REPORT OF SURVEY

SANTA CLARA - VENTURA RIVERS and CALLEGUAS CREEK WATERSHEDS

CALIFORNIA

For Runoff and Waterflow Retardation and Soil Erosion Prevention

U. S. DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE

3 SANTA CLARA-VENTURA RIVERS AND
CALLEGUAS CREEK WATERSHEDS,

CALIFORNIA.

Program for Runoff and Waterflow Retardation and Soil Erosion Prevention

Pursuant to the Act approved June 22, 1936 (49 Stat. 1570), as amended and supplemented.

September 1953

C O N T E N T S

INTRODUCTION

Authority. This survey report is submitted under the provisions of the Act approved June 22, 1936 (49 Stat. 1570) as amended and supplemented.

Scope. The survey was made to determine the floodwater, sediment and erosion problems in the Santa Clara-Ventura Rivers and Calleguas Creek watersheds, and to develop a watershed program of runoff retardation and soil-erosion prevention.

The watershed program is composed of two groups of measures. One group consists of measures primarily for flood prevention, hereinafter called flood-prevention measures (A Measures), which are not now normally being installed under existing authorities for current national programs of the Department of Agriculture. The other group consists of measures used for the conservation of watershed lands which contribute directly to flood prevention, hereinafter called land treatment measures (B Measures), and which are being installed under existing authorities for such programs.

This report presents recommendations for authorization of the flood-prevention measures under the Flood Control Act of June 22, 1936, as amended and supplemented, and for installation of the land-treatment measures under existing authorities concurrently with the flood prevention measures.

Need for the Watershed Program. Damages from floods and storm runoff average about one million dollars a year. One flood, in 1938, produced damages of 4-1/2 million dollars. When floods occur, many

towns are either inundated or isolated by destruction of roads, bridges, and railroad facilities. The population of the area has increased 50 percent since 1940. This has led to increased residential development in flood hazard areas, which has increased the damage potential correspondingly.

Water shortages for nine months of the year have become as critical as recurrent flood damages during the three-month rainy season. Groundwater, the main source of domestic and irrigation water supplies, is diminishing seriously in some parts of the area. This is due in part to heavier withdrawals, but also to watershed conditions which permit too much surface runoff at the expense of groundwater replenishment. Widespread gullying on agricultural soils is evidence of land mismanagement.

Local interests have constructed the first of several planned flood-control and water-conservation reservoirs which are to store the flashy winter runoff for later release to groundwater basins. This surface storage space will be expensive and the life of these planned reservoirs should be prolonged by the immediate initiation of erosion-control measures to reduce present high rates of sedimentation.

RECOMMENDATIONS

It is recommended that:

(a) The Secretary of Agriculture be authorized to install the flood-prevention measures on a cost-sharing basis 1/ with local

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1/ The share of the cost to be borne by local interests may consist of cash, labor, materials, equipment, land easements, rights-of-way, and other contributions. ~~in lieu of cash payments.~~

interests during a 20-year period in the Santa Clara-Ventura Rivers and Callegugas Creek watersheds in California under the provisions of the act of June 22, 1936, as amended and supplemented, at an estimated Federal cost of $5,048,900.

(b) The land-treatment measures, for which no additional authority is requested herein, be applied under existing authorities concurrently with the installation of the flood-prevention measures to assure the proper functioning of the program.

(c) As a condition precedent to the installation of the program, cooperating State and local agencies be required to furnish assurances satisfactory to the Secretary of Agriculture with respect to their ability and willingness to operate and maintain the flood-prevention measures on non-Federal land.

(d) The authority of the Secretary of Agriculture to carry out the flood-prevention measures be supplemental to all other authority vested in him, and that nothing in this report will be construed to limit the exercise of powers heretofore or hereafter conferred on him

by law to carry out such measures or other measures that are similar or related thereto.

(e) The Secretary of Agriculture be authorized to construct such buildings and other improvements as are needed to carry out the flood-prevention measures.

DESCRIPTION OF WATERSHED

One large and two small watersheds have been combined for this report. See Map 1. The Santa Clara River, the largest of the three drainages, is flanked by the Ventura River on the north and Calleguas Creek on the south. The accompanying map shows the general location and outline of these watersheds. These streams flow into the Pacific Ocean about 60 miles northwest of Los Angeles. The total area of the combined drainages is 2,173 square miles or 1,390,720 acres. Together, these three drainages are referred to in this report as the Santa Clara group of streams.

The Ventura River watershed is fan-shaped, about 32 miles long, with an area of 228 square miles (145,920 acres). The watershed includes two major physiographic units: (1) the steep, rocky, chaparral-covered Santa Ynez Mountains, which rise abruptly from the Ojai, Upper Ojai, and Santa Ana Valleys; (2) the more rounded coastal hills, covered with grass-oak-sagebrush vegetation, and lying between the mountains and the ocean.

The Santa Clara River heads north of Los Angeles and flows westward for approximately 90 miles to the ocean. The area is about 1,620 square miles (1,036,800 acres). Most of the watershed is rough,

mountainous land, largely covered with chaparral and sagebrush. Only about 10 percent is valley floor and coastal plain. The mountains in the western and most rugged portion are rough and broken, characterized by long ledges of out-cropping rock and precipitous escarpments. The major portion of the watershed, however, is composed of moderately rough mountains and semidesert valleys.

Calleguas Creek watershed has an area of 325 square miles (208,000 acres). It is oval in shape, about 30 miles long and 14 miles wide. The topography is moderate, elevations ranging from sea level to 3,600 feet in the Santa Susana Mountains. Calleguas Creek generally has well-intrenched watercourses except in the lower reach of Oxnard Plain, a level coastal area between the mouths of Santa Clara River and Calleguas Creek.

The geologic formations of the Ventura watershed are of sedimentary origin; principally well-cemented, interbedded sandstones, shales, and conglomerates. Scattered through the area are numerous old terrace deposits. Along the streams are deep deposits of recent alluvium. The Santa Clara Basin is underlain by an impervious basement complex of pre-Jurassic schist, quartzite, slate, granite and limestone. The basement complex, partially overlain by friable sandstones, conglomerates, and shales, is exposed over large portions of the mountains and foothills. The Calleguas Creek watershed is also underlain by a basement complex of crystalline rocks. The surface rocks are sandstones, shales, and conglomerates, plus Quaternary alluvium and terrace deposits. In the lower portions of all of the drainages there is a

deep valley fill. Practically all of the commercial water wells are drilled in this aquifer which acts as an underground reservoir.

The mountain soils average about two feet in depth and contain many rock fragments. They are capable of maintaining a good vegetative cover if protected from fire and overgrazing. The soils formed from semiconsolidated and unconsolidated sediments are especially susceptible to severe erosion when the vegetative cover is removed.

The dominant agricultural soils are deep alluvial material in the Oxnard Plain and in the valley bottoms of the Santa Clara River and Calleguas area. A less extensive but important type is the old valley-fill soils. They occur in very hilly or rolling areas, on terraces or sloping remnants of old alluvial fans which have been elevated since their deposition. The subsoils are more compact and heavier in texture than the surface soils, with tendencies toward hardpan development. They are susceptible to severe erosion when cultivated. Agricultural lands are generally well drained and productive.

Continuous flow throughout the length of the channel in the Santa Clara group of streams is evident only during the rainy season and, in many instances, only during periods of flood flows. The valley fill over which streams flow usually absorbs most of the water before it joins the main river. In flood the mountain reaches of the streams are heavily laden with debris. On leaving the steep mountain canyons they lose their transporting power and the load of debris is dropped, except for the fine material which is moved farther downstream with each flow and is eventually delivered to the ocean.

The climate is characterized by long, dry summers and short, wet winters. Cool, moist winds from the ocean have a moderating effect upon the climate. Frost is rare in the coastal area but common in the inland and mountain regions. Recorded temperature extremes at Oxnard, on the coastal plain, are 104 degrees F. and 26 degrees F. About 75 percent of the annual precipitation occurs from December to March, inclusive. Mean seasonal precipitation varies from about 8 inches in the valley area at the head of the Santa Clara River to about 40 inches in the Topatopa Mountains and 14 inches on the coastal plain. Snow normally covers the higher peaks in winter but is not a contributary factor to the flood problem.

The equable climate and deep valley soils attracted early settlers to this area. Soon after the establishment of San Buenaventura Mission in 1782, and before 1850, large areas passed into private hands by way of Mexican land grants. During this early period the raising of livestock was the major industry. American immigrants settled in the Santa Clara Valley about 1850. Agriculture soon became the principal industry; grain was grown as early as 1872; the first olive grove was planted in 1873; and the first orange grove in 1874. When the feasibility of growing citrus was established, most of the irrigable land was planted to this crop. Citrus, beans, walnuts, sugar beets, grain, and hay are now the most important crops. Today the growing, packing, and shipping of agricultural products is the basic industry. Oil production and refining are the only other major industries.

About 40,000 acres in the Santa Clara River basin and about the same acreage on the Oxnard Plain are irrigated. All but a small portion

of irrigation water is supplied by pumping from the underground aquifers. Direct diversion is possible only during winter and spring when the streamflow is available for distribution to a very limited acreage. Only a few hundred acre-feet are stored in reservoirs.

The area is now criss-crossed with State and Federal highways and two main lines of the Southern Pacific Railroad.

Population of the area generally has increased about 50 percent since 1940. During the war years Port Hueneme was improved and became a port of supply for the Navy. A large naval training station is also maintained. At Point Mugu there are installations for guided missile research.

This early development of the valley areas bordering the main streams created a paradoxical water problem. From the earliest development, floods menaced the valley settlements and agricultural lands. Then as irrigated agriculture became more intensively practiced, the conservation of water assumed greater importance. Today, flood-waters discharging from these watersheds during the short winter months rarely reach the underground basins for later beneficial use. Most of it wastes into the ocean. Yet the remainder of the year creates heavy demands for irrigation and domestic water, most of it pumped from the underground basins. Water shortages nine months of the year have become as critical as recurrent flood damages experienced in the three months of the rainy season.

The streams of the Santa Clara group produced great natural aquifers by filling the bedrock basins with material eroded from the

mountains. Shortage of water is becoming more critical each year in the Calleguas Creek drainage since recharge has been less than draft during the last series of wet years. The major portion of the recharge of the Oxnard Plain, which is pumped very heavily, comes from the Santa Clara River. Piru and Sespe Creeks furnish 55 to 60 percent of the Santa Clara River runoff. Between 1944 and 1946 there was a 70 percent increase in the volume of water pumped for irrigation and domestic use in the Santa Clara drainage. The greatest water shortage occurs on the Oxnard Plain below Montalvo. Here the pumping level has dropped, salt water is intruding near the coast, and the direction of ground-water flow has been reversed in Pleasant Valley. The overdraft amounts to 30,000 acre-feet during drought conditions. Attempts to correct this overdraft have been confined largely to the construction and operation of spreading grounds. The average annual quantity of water conserved by spreading is 16,560 acre-feet. Good watershed conditions are essential to successful water spreading since silt-laden flood flows cannot be used.

Development of these three drainages also has been accompanied by a corresponding modification of the native vegetation which, in turn, has influenced runoff and erosion. The good soils of the valleys are under cultivation and the bench and foothill lands are, or at one time have been, under cultivation wherever topography permitted. Extreme overgrazing has been practiced on the lands grazable by livestock. Early records indicate that great fires burned and reburned the area before fire control was achieved during the early years of the Civilian

Conservation Corps program. Oil field development, although the area affected is small, is responsible for some glaring examples of road and site development which have resulted in long slopes of exposed bare soil.

As a result of early abuse, the vegetative cover has been modified in many respects. The conifer, woodland, and mixed chaparral types have been reduced in area and capacity to retard surface runoff and prevent erosion. There is a marked tendency for many of the most valuable litter-building species to decrease with repeated burnings, invariably resulting in deterioration of both cover and site. The importance of the native cover is evident when it is realized that it occurs on 86 percent of the surface area. The two main types are sagebrush and chaparral, which make up 24 percent and 54 percent, respectively, of the total area of native cover.

The deteriorated condition of watershed cover is reflected in increased erosion and resultant deposition. This movement of debris bulks flood flows and when deposited in the stream channels reduces channel capacity, thereby increasing flood damage. The average annual erosion rate is high, ranging from about 700 to 5,200 cubic yards per square mile per year.

Water erosion on agricultural land affects all sloping land to an extent dependent upon slope, soil, and cropping practice. The most serious sheet erosion occurs on old alluvial fill lands which have been dry-farmed to beans. Gully erosion is common in all agricultural soils except on the coastal plain. Barrancas have cut deeply in many areas of the best recent alluvial soils.

FLOOD PROBLEMS

General descriptions of floods in the area date back to 1811, indicating that five great floods and thirty medium and large-sized floods have been experienced in the Santa Clara River. Because of similar hydrologic conditions for the Ventura River, its flood history has been roughly the same as that of the Santa Clara River. Calleguas Creek is somewhat at variance with the Santa Clara and Ventura Rivers. Occasionally only moderate precipitation is recorded on Calleguas Creek when high-intensity rainfall and floods are produced in the Santa Clara basin.

Damage is high to all improvements when floods occur. On farms, topsoil is eroded, crops are destroyed, farm equipment buried under debris or washed away, livestock is drowned, and fields are covered with debris. Land along the rivers, creeks, and barrancas is cut away. The numerous small towns are either inundated or isolated by destruction of roads, bridges, and bridge approaches. Rail communications are interrupted by destruction of tracks and bridges and by deposition of debris. As an example, during the 1938 flood the Southern Pacific lost eleven bridges and 4 miles of track in Soledad Canyon in the upper Santa Clara watershed. The 1938 flood was the largest of recent flows, and a detailed survey by the Corps of Engineers revealed damages of $4,500,000.

Total average annual flood and sediment damages to present and anticipated future economic development without a remedial program, for the areas investigated in this report, are estimated to be $1,134,000 (Table 1).

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Table 1
ANNUAL FLOOD AND SEDIMENTATION DAMAGES
Santa Clara-Ventura-Calleguas Creek Watersheds
(Long-term projected prices)

Floodwater damage 1/	$ 847,200
Channel sedimentation damage 2/	122,400
Reservoir sedimentation damage 3/	43,700
Indirect damage	120,700
	$1,134,000

1/ Includes damage to agricultural land and crops, urban and industrial property, communication and transportation facilities, etc.

2/ Includes evaluated damage occurring in Calleguas Creek channel only. Similar damage in other channels not estimated because of inadequate data.

3/ Includes evaluated damage to Matilija Reservoir only. Similar damage to other reservoirs not estimated because of inadequate data.

The sedimentation problem is of paramount importance in relation to the water-conservation reservoirs now constructed or under study. From studies of the relation of sedimentation to discharge and watershed characteristics in adjacent watersheds, the annual rate of sediment production for the Santa Clara and Ventura Rivers and for Calleguas Creek is estimated to be about 4,100 cubic yards per square mile under expected future conditions without remedial measures.

ACTIVITIES RELATED TO FLOOD CONTROL

During the past 40 years local interests, county and State agencies, and a railroad company have spent more than $1,000,000 for the

construction and maintenance of flood-control improvements and for the cleaning of channels along relatively short sections of the Santa Clara River and its tributaries. The principal improvements have been levees, jetties, revetments, and various types of bank protection, channel paving, and channel clearing. These works were intended to protect agricultural land from bank cutting, and to protect highways, railroads, bridges, and small towns. They are mostly inadequate and maintenance costs have been excessive. See Map 2 for the location of existing and proposed works of the major agencies.

Along upper Calleguas Creek individual property owners, groups of owners, and a Soil Conservation District, have constructed small channel improvements consisting of pipe and wire revetments, small drops, and check dams to stabilize channel gradients. On the Oxnard Plain the State, Ventura County, a beet sugar factory, and a large ranch have cooperated in construction of a leveed channel.

About $100,000 has been spent by local interests along the Ventura River for short sections of leveed channel, channel excavation, and clearing. These improvements are temporary in nature or inadequate to withstand major floods.

Until recently this area had no major reservoirs. There are two reservoirs in the upper Santa Clara River basin, Bouquet and Dry Canyons, but these are operated solely to regulate the flow in the aqueduct which conveys water from the Owens River Valley to Los Angeles. Without ground-water pumping the present development of the area could not have occurred, since precipitation is too small

and too unevenly distributed to produce streamflow sufficiently large and dependable to permit continuous diversion of unregulated flows. In 1944 the Ventura County Flood Control District, covering the entire county, was created under State legislation. The county then undertook comprehensive investigations of the problem of conserving runoff and controlling floods from its major streams. In 1943 residents of the Ventura River watershed voted $3,400,000 in bonds for construction of flood-control, water-conservation reservoirs on Matilija Creek and Coyote Creek, tributaries of Ventura River. The Matilija reservoir, of 7,000 acre-feet capacity, is now completed; and final details of the proposed Casitas reservoir on Coyote Creek are being developed by cooperative State-County field and office studies. 2/

The Santa Clara Water Conservation District was formed in 1928 to protect water rights, investigate water-supply problems, and construct works for water conservation. The District comprises about 100,000 acres in Ventura County, including most of the irrigable lands of the Santa Clara River Valley and Oxnard Plain. It has constructed works for spreading water over porous areas in several localities, and at times has scarified portions of the river bed to increase percolation into underlying gravels. No special protection from floods has been provided. No water is diverted for spreading during floods or afterwards until the water has become relatively clear. An 87-acre extension of one of the spreading basins was recently completed, but this will not be adequate to meet demands. The District has made

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2/ The Casitas reservoir site is also known as the Hoffman site.

comprehensive engineering studies of its water needs and sources of supply. Storage reservoir sites exist on both Piru and Sespe Creeks, tributaries of the Santa Clara. These sites have been under consideration for many years. Fifty-five to 60 percent of the total river discharge comes from Piru and Sespe Creeks, and all feasible reservoir sites are on these two tributaries.

Water-supply and flood-control reservoirs have not previously been built on Piru and Sespe Creeks because of the very expensive construction, especially for the capacity that would be required to maintain the desired yield over the periodic dry cycles. It is not certain that reservoirs of sufficient capacity for carry-over during the longer dry periods can be afforded by water users. Another reason for postponing construction of reservoirs was the realization that sedimentation will be high and local interests did not want to lose any of the precious storage space by construction before absolutely necessary. Engineering and legal steps have now been initiated leading to the selection of the best sites and their early construction.

The Department of the Army, Corps of Engineers, recommended a plan for the protection of the cities of Ventura and Ojai which was authorized by the 1944 Flood Control Act. The improvements consist of a 2.6 mile levee at the city of Ventura, a debris basin at the mouth of Stewart Canyon above Ojai, and a concrete channel extending from the debris basin through the city. The estimated total Federal installation cost was $1,604,000 plus a total non-Federal first cost of $135,000 for utilities relocation, highway and railroad bridges,

and rights-of-way. A debris storage sump was constructed in 1949 at the mouth of Stewart Canyon to provide temporary protection to Ojai against flood damage from the 25,000 acres burned in 1948. The Ventura River levee has been completed, but construction of the authorized works at Ojai has not been started.

On the Santa Clara River the Corps of Engineers has recommended construction of a 5-mile paved levee along the south bank of the river to protect Oxnard Plain, and a concrete channel for the lower 3 miles of Santa Paula Creek to protect the city of Santa Paula. The Federal first cost was estimated at $3,010,000. This project has been authorized and advance planning studies are under way, but as yet construction funds have not been appropriated.

In 1942 a survey report was made by the District Engineer, Los Angeles Office, Corps of Engineers, on flood control for Calleguas Creek. The report concluded that the improvements considered were not economically justified and recommended that no flood-control project be undertaken at that time.

The Department of Interior, Bureau of Reclamation, has no authorized or proposed projects or investigations in the report area.

The Department of Agriculture is actively cooperating with State and local agencies in carrying out programs for conservation of soils and water resources of the watershed. The Forest Service administers and provides fire protection for approximately 717,500 acres of national-forest land. This acreage represents one-half of the area in combined drainages. This mountain land is of paramount importance as the source

of water for irrigation and municipal use as the valley lands add only a negligible amount of water to the underground supply. Consequently, the maintenance of good watershed conditions is required if (1) the maximum amount of precipitation is to percolate into the underground basins, (2) silt-free water is to be available for spreading, and (3) damaging sedimentation is to be kept to a minimum. The State of California, through Santa Barbara and Ventura Counties, cooperates with the Forest Service in the protection of qualified State and private lands against fire. The Forest Service has also provided emergency treatment to large burned areas where threat of flood damage existed. The Department of Agriculture, through its ACP program, offers financial assistance to farmers for carrying out soil- and water-conservation practices on privately owned lands. The Department also cooperates with State Extension Service and Experiment Stations in educational and research work in the conservation of soil and water resources. The Soil Conservation Service is currently assisting Soil Conservation Districts in the application of soil and water conservation measures on farmlands.

The Department of the Interior, Geological Survey, the Division of Water Resources of the State of California, and local agencies have made investigations of water yield, use, and conservation. The counties of Los Angeles and Ventura handle fire protection in rural areas outside the national forests with financial assistance from the State. The Los Angeles County Flood Control District covers much of the upper Santa Clara River watershed which is in that county. In recent years

the District has constructed channel and bank-protective works on the main river and several tributaries in scattered localities as the need arose. The total amount of work done by the District in this watershed to date is small.

The State of California, in cooperation with the Forest Service, has planted beaver on tributaries of Sespe Creek. To date these plants are considered as successful in maintaining streamflows during the low-flow periods and providing improved fish habitat.

The Soil Conservation Districts have been organized under the State enabling act, with a total area of 700,000 acres. The Soil Conservation Service provides technical and other assistance to implement the conservation activities of the districts.

RECOMMENDED PROGRAM

The program recommended in this report is designed to meet the needs of the Santa Clara-Ventura Rivers and Calleguas Creek group of watersheds for runoff and waterflow retardation and soil-erosion prevention. It consists of two groups of interrelated measures, which are designated as flood-prevention measures (A Measures), and land-treatment measures (B Measures).

The recommended measures were developed from studies, covering the entire area of the watershed, designed to provide a balanced and economically feasible remedial program. The proposed program assumes that the land-treatment measures are complementary to and must be carried out concurrently with the installation of those designated as flood-prevention measures. The present condition of the watershed

lands and stream courses was considered in detail to develop the most effective and economical combination of measures to reduce floodwater and sediment damages.

The recommended program to aid in the control of floods and sedimentation is designed to reduce flood damages and to protect and maintain the efficiency of the downstream flood-control and water-conservation works. It is an integrated program of cover protection and maintenance, control of active sediment source areas, stream-channel improvement and correction, and cropland-treatment measures.

The recommended flood-prevention and land-treatment measures are described in the following section of the report.

FLOOD-PREVENTION MEASURES
(A Measures)

Stream-channel improvement was the only flood-prevention measure found to be economically justified at the time the survey was made. Other measures which were investigated, but found to be not feasible at that time, are discussed subsequently.

Stream-Channel Improvement.--This item includes gully control on both lowlands and uplands as well as improvement of stream channels in agricultural sections of the watersheds. It consists of stabilizing existing gullies with permanent structures, enlarging inadequate channels for control of runoff, and channelization of flow on alluvial fans where agricultural development has almost eliminated natural stream courses. These improvements are primarily in the nature of lined channels, small dams and earth channels or

natural streams with required revetments and stabilizing structures, depending on specific site conditions. Also included is provision for collecting basic data needed for guiding program installation and operation and testing the effectiveness of the program. A total of 144 miles of this type of improvement is recommended.

LAND-TREATMENT MEASURES
(B Measures)

Protected Outlets.--Protected outlets such as seeded waterways, chutes, flumes, drops, and pipelines are needed on about 22,700 acres to provide for disposal of concentrated runoff from cropland to improved stream channels.

Terraces and Diversion Systems.--Terraces and diversion systems are required on some 8,700 acres of dry farmed land to provide erosion control on long slopes by intercepting runoff before damaging concentrations of water occur.

Establishment of Permanent Cover.--Establishing permanent cover is recommended on 25,800 acres of severely eroded cropland which should be retired from cultivation to prevent further land deterioration and to reduce excessive sediment production from these areas.

Establishment of Annual Winter Cover Crops.--Establishing annual winter cover crops is recommended on about 4,800 acres of irrigated cropland not now adequately protected from erosion.

Cooperative Forest Fire Control.--An expanded Cooperative Forest Fire Control program is needed to reduce the annual rate of burn to 0.2 percent on 450,500 acres of non-Federal land having inflammable

cover. The following items are typical of the kinds required to accomplish this objective: Additional access and transportation facilities to permit speedier attack on all fires; improved detection and communication in reporting fire occurrences; additional water developments for fire suppression; buildings for equipment and fire-control personnel. The cost of installing and maintaining this measure will be in addition to regular agency activities.

Fire Control.--Expansion of fire-control facilities is needed to reduce the annual rate of burn to 0.2 percent on 717,500 acres of national-forest land. The following items are typical of the kinds required to accomplish this objective: Additional access and transportation facilities to permit speedier attack on all fires; improved detection and communication in reporting fire occurrences; additional water developments for fire suppression; buildings for equipment and fire-control personnel.

Fencing.--Construction of 250 miles of fences is recommended to improve livestock distribution and eliminate excessive use and trampling on present concentration areas during wet weather. One-half of the fencing is proposed for non-Federal land, one-half for Federal land.

Stock-Water Developments.--About 100 additional stock-water developments are needed to bring about more uniform utilization of range forage. New water developments will permit better use of range areas which have been little used because of inadequate watering facilities. Better utilization of these lands will

relieve pressure on more heavily grazed areas. Of the total need, 50 are needed on non-Federal land, and 50 on Federal land.

Range Reseeding.--Reseeding is needed to reduce erosion and improve the forage on 10,000 acres of depleted rangeland which would not produce an effective cover within a reasonable length of time without reseeding. About 5,000 acres of the reseeding is planned for non-Federal land, the balance for Federal land.

Technical Services, Open Land.--Technical services will be made available for planning and applying the necessary land-use adjustments and for applying conservation measures on crop and range lands, and for integrating these measures with other measures included in the recommended program.

Educational Assistance.--Landowners, operators, and other groups will be furnished educational assistance relative to the need for the recommended program and its purpose and objectives. Information will be supplied as to the manner in which landowners and operators now obtain services and assistance that are available through the various governmental agencies, and how they can and should by their own efforts contribute successfully and most economically to the accomplishment of the over-all objectives. Intensified educational efforts will be directed to familiarizing farmers with the specific practices and measures essential to runoff and waterflow retardation and soil erosion prevention, and how to install and apply these measures not requiring the assistance of a specialized technician. How to maintain such installations and measures will be emphasized. Instruction

will be given on how to integrate all into a sound farm management system to produce the greatest benefits over a long period of time.

COST OF RECOMMENDED PROGRAM

The estimated cost of installing both the flood-prevention measures and the land-treatment measures is $12,662,700. It is estimated that local interests will provide 36 percent of the cost of installing these measures on non-Federal land; however, the allocation of Federal and non-Federal costs will vary by types of measures. The cost of installing land-treatment measures on non-Federal land will generally be borne in large part by individual landowners and operators since a large part of the benefit will accrue directly to the land on which the measures are applied. Flood-prevention measures, however, produce public benefits often of a dispersed nature, and extending far downstream. The Federal Government will install these latter measures on non-Federal land on a cost-sharing basis, and will provide a larger share of the cost of installation than in the case of land-treatment measures. The cost of installing, operating, and maintaining both flood-prevention and land-treatment measures on Federal land will be borne by the agencies responsible for the administration of such land.

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FLOOD PREVENTION MEASURES
(A Measures)

The estimated cost of installing the flood-prevention measures is $6,356,300 (see Table 2). Of this cost, it is estimated that the Federal Government will expend $28,000 on Federal land and $5,020,900 on non-Federal land, and that local interests will expend $1,307,400 on non-Federal land.

Local interests will be required to furnish without cost to the Federal Government all land, easements, and rights-of-way needed in connection with the installation of the flood-prevention measures; and will be expected to make any additional contributions that may be necessary to meet their proportionate share of the cost of installing these measures as determined by the Secretary of Agriculture to be equitable in consideration of the anticipated benefits from such measures.

The estimated annual Federal cost of operating and maintaining these measures on Federal land is $800. The estimated annual cost of operating and maintaining these measures on non-Federal land is $163,000 which will be borne by local interests.

Table 2
ESTIMATED COST OF INSTALLING FLOOD PREVENTION MEASURES
(A Measures)
Santa Clara-Ventura-Calleguas Creek Watersheds
(Long-term projected prices)

Measure	Unit	Quantity	Cost Federal 1/	Cost Non-Federal	Cost Total
			(dollars)	(dollars)	(dollars)
Stream channel improvement					
Federal land	Mi.	6	28,000	-	28,000
Non-Federal land	Mi.	138	5,020,900	1,307,400	6,328,300
Total		144	5,048,900	1,307,400	6,356,300

1/ Includes cost of collecting basic data needed for guiding program installation and operation, and testing effectiveness of the program.

LAND-TREATMENT MEASURES
(B Measures)

The estimated cost of installing the land-treatment measures is $6,306,400 (see Table 3). Of this cost, it is estimated that the Federal Government will expend $2,703,000 on Federal land and $1,319,500 on non-Federal land. The estimated Federal cost of these measures on non-Federal land does not include financial assistance by the Federal Government such as Agricultural Conservation payments to landowners and operators. Any assistance of this kind that may be provided at the time of program installation will help landowners and operators in installing the program.

The estimated annual cost of operating and maintaining these measures is $485,600. Of this amount, it is estimated that the Federal Government will expend $227,900 on Federal land and $97,000 on non-Federal land; and that local interests will expend $160,700 on non-Federal land.

Table 3
ESTIMATED COST OF INSTALLING LAND TREATMENT MEASURES
(B Measures)
Santa Clara-Ventura-Calleguas Creek Watersheds
(Long-term projected prices)

Measure	Unit	Quantity	Cost Federal (dollars)	Cost Non-Federal (dollars)	Cost Total (dollars)
Protected outlets					
Non-Federal land	Acre	22,700		635,000	635,000
Terraces and Div. systems					
Non-Federal land	Acre	8,700		200,100	200,100
Estab. of permanent cover					
Non-Federal land	Acre	25,800		422,700	422,700
Estab. of annual winter cover crops					
Non-Federal land	Acre	4,800		19,700	19,700
Cooperative forest fire control					
Non-Federal land	Acre	450,500	803,700	803,700	1,607,400
Fire control					
Federal land	Acre	717,500	2,521,300		2,521,300
Fencing					
Non-Federal land	Mile	125		60,400	60,400
Federal land	Mile	125	60,400		60,400
Stock water developments					
Non-Federal land	No.	50		24,200	24,200
Federal land	No.	50	24,200		24,200
Range reseeding					
Non-Federal land	Acre	5,000		97,100	97,100
Federal land	Acre	5,000	97,100		97,100
Technical services -- open land			494,800		494,800
Educational assistance			21,000	21,000	42,000
Subtotal - Federal land			2,703,000	-	2,703,000
Subtotal - Non-Federal land			1,319,500	2,283,900	3,603,400
Total			4,022,500	2,283,900	6,306,400

BENEFITS FROM THE RECOMMENDED PROGRAM

Physical Effect.--The combined effects of all measures will reduce excessive surface runoff and promote infiltration of rainfall into the soil and rock strata with a consequent decrease in the magnitude of flood peaks. The average reduction in floodwater damages will be about 50 percent. Benefits accruing from soil erosion prevention will be lessened flood peaks, conservation of valuable crop and range lands, and maintenance of agricultural yields. Additional benefits from the program will be reduced property loss by fire, prevention of loss of agricultural land, reduced fire suppression costs, and increased rental return on cropland. These benefits have been evaluated in terms of dollars.

Monetary Benefits.--Monetary benefits represent the difference between expected future flood damages plus farm and ranch income with and without the recommended program. Future flood damages are expected to increase unless a remedial program is installed.

Total annual benefits, as shown in Table 4, are about $1,192,300, of which $606,500 are flood and sediment control and $585,800 conservation and other incidental benefits. Attainment of the benefits described in this report is dependent on the installation and proper maintenance of all recommended measures and practices.

Table 4
ESTIMATED AVERAGE ANNUAL MONETARY BENEFITS FROM THE RECOMMENDED PROGRAM
Santa Clara-Ventura-Calleguas Creek Watersheds
(Long-term projected prices)

Type of Benefit	Average Annual Benefits
	(dollars)
Reduction in floodwater damage	434,600
Reduction in channel sedimentation damage	79,200
Reduction in reservoir sedimentation damage	27,800
Reduction in indirect damage	64,900
Reduction in fire suppression cost	66,300
Reduction in property loss by fire	49,000
Increased range returns	91,600
Reduction in road maintenance cost	74,500
Maintenance of crop yields	304,400
Total program benefits	1,192,300

Unevaluated Benefits.--Many other benefits, less susceptible to monetary evaluation, will accrue from the program. These unevaluated benefits are highly important in relation to the social and economic welfare of the watershed. These additional unevaluated benefits include:

(1) The extended usefulness of existing and contemplated reservoirs and their facilities which are essential to the permanency of the area's irrigated agriculture and its dependent economy. At present the growth and development of the area's economy are solely dependent upon its limited local water supplies. There are no nearby feasible sources of water for importation. The loss of reservoir storage capacity due to sedimentation would therefore produce a profoundly adverse effect on the economy of this area over and above the readily evaluated effects.

[illegible]

[illegible]

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
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[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

[illegible]

[illegible]

(2) Increased productivity of watershed soil and forage resources. Average sediment production now ranges from 900 to 4,700 cubic yards per square mile annually under present watershed conditions. Expected future watershed conditions without a treatment program will increase this average annual yield to about 1,000 to 6,500 cubic yards per square mile. Installation of the recommended program will reduce (a) the rate of soil loss to about 300 to 2,900 cubic yards per square mile per year, and (b) the need for future heavy expenditures for soil improvement and stabilization.

(3) Greater stability of business and employment. The program will result in an increase in the sustained annual production of agricultural produce and livestock. The program on cultivated land will, in some cases, permit a conversion to higher value crops with resultant higher land values. These increases will not only help stabilize and improve the economic condition of the owners and operators of the land but also that of local labor and the business dependent upon a steady community income.

(4) Enhanced recreational opportunities, including hunting and fishing. The recommended program will improve streamflow conditions and make possible the gradual improvement of waterways through reduced sedimentation and more sustained year-long flows. Recreation in the form of picnicking, camping, fishing, and hunting constitutes the second most important resource in the wildland section, following its importance in water production and control.

(5) Reduced maintenance costs of utility and transportation lines. Due to the generally rugged terrain, utility and transportation lines have suffered occasional increased maintenance costs resulting from storms upon fire-denuded slopes. This increased maintenance continues for several years until a vegetative cover is reestablished. The program of intensified fire control will reduce the average annual amount of wildland burned over. Data were available for an evaluation of the extent to which the cover protection program would prevent an expected increase in road and highway maintenance costs. Lack of data prevented an evaluation of corresponding benefits to other services such as railroads, telephone and telegraph lines, oil, gas and water lines, aqueducts, and electric power transmission lines, but observation of past fire-storm damage shows that the benefit would be large.

COMPARISON OF BENEFIT AND COST

The ratio of the estimated average annual monetary benefit of $1,192,300 to the estimated average annual value of the total cost of $987,900 of the recommended program is 1.21 to 1.0. This ratio has been computed on the basis of long-term projected prices.

Figures in this report (on a broad basis) are based on the best readily available data and information. In the event the report is authorized, detailed work plans and designs will be made and firm figures on costs and benefits will be determined for individual tributaries prior to the initiation of installation work.

OTHER MEASURES CONSIDERED BUT NOT RECOMMENDED 3/

The principal benefit of the following considered measures is the reduction of sedimentation in downstream reservoirs and in the main rivers. At the present time several factors prevent adequate appraisal of such reduction in sedimentation damage: (1) the uncompleted state of current water-conservation studies; (2) lack of sufficient basic data on the effect of sedimentation on main river channels; and (3) lack of sound and realistic bases for evaluating sedimentation effects on both channels and reservoirs. If these three problems are solved, the measures discussed below should be reconsidered and re-evaluated.

At present the report area has reached the stage where lack of water limits further development and, in fact, cannot support the present economy in the periodic dry cycles. For this reason local interests have created water-conservation organizations and are planning to augment their present undependable supply by reservoirs to conserve the now unregulated flow of the rivers. One of the reasons for postponing reservoir construction until absolutely necessary was the known high rate of sedimentation which rapidly affects the costly water-storage space. As soon as reservoirs now being planned are definitely scheduled for construction, studies should be undertaken to develop specific and intensive measures to reduce sedimentation to the minimum practicable levels.

3/ Practically all of the other measures considered here would be classified as flood-prevention or A measures.

It is felt that sedimentation in the main river channels, especially the Santa Clara River, augments the damage caused by flood flows but present data and surveys are not sufficiently conclusive to permit estimation of the effect of sedimentation on channel capacities and current deflection. Since an accurate evaluation of channel sedimentation is not possible at present, it would be impossible to develop the extent of corresponding erosion reduction which would be justified. Sufficient data should be developed in the near future to permit this determination.

(1) Road Stabilization.--In general, roads throughout the watersheds are in comparatively good condition. However, drainage facilities are not adequate. There are not sufficient cross-drainage structures to properly collect and bypass the water falling on and above the roads. Disposal flumes are generally of insufficient length to dispose of the water to points where erosion will not result. There are also bare eroding fill slopes which must be revegetated before the soil can be stabilized.

On the basis of an erosion survey of Los Padres National Forest, made in 1946, a plan of improvement was developed for 174 miles of wildland roads. The plan included the installation of drainage structures, disposal flumes, gully plugs, and check dams to control drainage gullies, diversion and interception ditches, and vegetative treatment of eroding slopes. The total cost of construction was estimated to be $852,000 with annual maintenance and replacement costs of $10,200. The physical effects of these measures would be the reduction of sedimentation amounting to about 40,000 cubic yards per year and reduction of road maintenance costs by about 75 percent.

Should such a program be considered for flood-control purposes it should be based on a new study which would take into account the present road conditions and the effect of recent storms in producing erosion and increasing maintenance costs. The estimates of the effects of the road improvement measures quoted above are based on studies made some years ago on roads in the nearby San Gabriel Mountains.

(2) Mountain Channel and Gully Stabilization.--A plan of gully and channel control was studied for the Piru Creek drainage area to reduce downstream reservoir and main river sedimentation and to reclaim valuable mountain meadow grazing lands. The work would involve the installation of gully plugs, check dams, debris barriers, and vegetative stabilization of banks. Permanent type structures were contemplated in about 25 miles of actively eroding stream channels where gullies have reached such large proportions that expensive structures and treatment are required.

Reconnaissance field surveys and office study of aerial photographs and small-scale maps form the basis for program estimates. The cost of the work would be approximately four and one-half million dollars. It was estimated that the plan would reduce sediment production an average of 100,000 cubic yards per year and reclaim several hundred acres of range and farm land. This plan was intended for installation at such time as planned water-control reservoirs are constructed.

A plan of debris control was considered for Matilija Creek to reduce siltation of the recently constructed Matilija Reservoir. The plan included about 15 small- to medium-size debris storage and channel stabilization dams and sills. The larger dams would be constructed at feasible sites where physical conditions allow the most economic control and detention of debris. The smaller structures would be installed in reaches of channel between the larger dams where stabilization of channel bed material is required to reduce channel scour.

The possibility of constructing these works in two stages was considered, the aim being to devise the optimum combination of channel debris storage by structures with the gradual reduction in erosion provided by the improved watershed cover resulting from intensified fire-control measures. The construction cost of the plan was estimated at about two million dollars.

Channel-control plans were considered for several other areas including Coyote Creek, Stewart Canyon, Sespe, and Santa Paula Creeks, the upper headwaters of the main Santa Clara River, and Castaic. All were found to be economically unfeasible at this time. Should large water-conservation or flood-control reservoirs be planned in these areas, consideration should be given to the simultaneous development of channel-stabilization works.

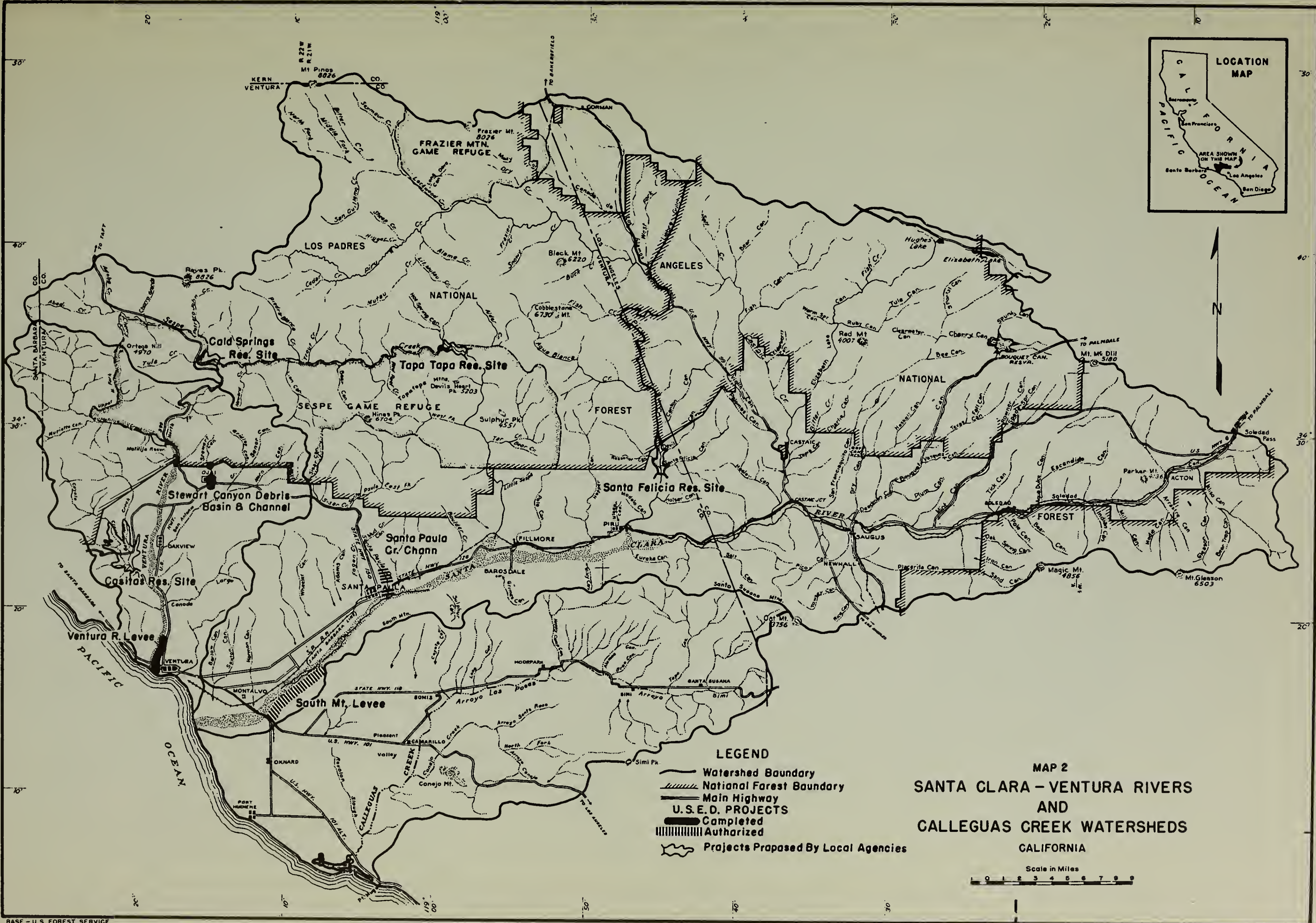
(3) Revegetation.--Maintenance and improvement of the present cover on mountain slopes can be accomplished largely by adequate fire protection. Nevertheless, large areas deteriorated by repeated

burning, critical south exposures, and semibarren areas need more than protection to re-establish the vegetation necessary for stabilization. The objective of the revegetation measures is to augment the fire-protection measures by improving certain deteriorated sites which will reduce their contribution to excessive runoff and erosion. This could be accomplished by planting native conifers in the areas from which they have been depleted by fire and in the existing sparse stands.

The aim was to attain a cover density of 50 percent in the sparse and denuded portion of the coniferous zone. It is estimated that a total of 6 square miles of forest land in the Sespe Creek drainage and 25 square miles in the Piru Creek drainage are in need of this treatment. In addition, litter-producing shrubs and trees would be planted adjacent to small tributary channels, utilizing the small pockets of better soil. The revegetation plan was estimated to cost about $800,000.

SANTA CLARA – VENTURA RIVERS AND CALLEGUAS CREEK WATERSHEDS

CALIFORNIA


LOCATION MAP
CALIFORNIA
PACIFIC OCEAN
AREA SHOWN ON THIS MAP
Santa Barbara
Los Angeles
San Diego
San Francisco
Sacramento
LOS PADRES
NATIONAL
FOREST
ANGELES
FRAZIER MTN. GAME REFUGE
SESPE GAME REFUGE
Cold Springs Res. Site
Tapo Tapo Res. Site
Santa Felicia Res. Site
Stewart Canyon Debris Basin & Channel
Santa Paula Cr. Chann
Casitas Res. Site
Ventura R. Levee
South Mt. Levee
SANTA CLARA RIVER
VENTURA RIVER
CALLEGUAS CREEK
PACIFIC
OCEAN
FILLMORE
SANTA PAULA
SAUGUS
NEWHALL
CASTAIC
ACTON
MOORPARK
CAMARILLO
OXNARD
MONTALVO
VENTURA
OAKVIEW
PORT HUENEME
BARDSDALE
PIRU
GORMAN
SOLEDAD
TO BAKERSFIELD
TO PALMDALE
TO TAFT
TO SANTA BARBARA
TO LOS ANGELES
KERN
VENTURA
CO.
SANTA BARBARA
LOS ANGELES
Mt Pinos 8826
Frazier Mt. 8026
Reyes Pk. 8826
Black Mt 6220
Cobblestone 6730 Mt.
Red Mt 4007
Sulphur Pk. 4551
Hines Pk. 6704
Mt. Mc Dill 5180
Magic Mt. 4856
Mt.Gleason 6503
Oat Mt. 3756
Conejo Mt.
Simi Pk.
Hughes Lake
Elizabeth Lake
Soledad Pass
LEGEND
Watershed Boundary
National Forest Boundary
Main Highway
U.S.E.D. PROJECTS
Completed
Authorized
Projects Proposed By Local Agencies
MAP 2
SANTA CLARA - VENTURA RIVERS
AND
CALLEGUAS CREEK WATERSHEDS
CALIFORNIA
Scale in Miles
0 1 2 3 4 5 6 7 8 9
N

v. 2
Appendices

REPORT OF SURVEY

SANTA CLARA - VENTURA RIVERS and CALLEGUAS CREEK WATERSHEDS CALIFORNIA

APPENDICES

For Runoff and Waterflow Retardation and Soil Erosion Prevention

U. S. DEPARTMENT OF AGRICULTURE

AGR-SCS-PORTLAND, ORE JULY 1953

SANTA CLARA-VENTURA RIVERS AND CALLEGUAS CREEK

Addendum - Appendix

Due to changes in Departmental policy regarding flood-prevention surveys, it was necessary to revise the Santa Clara-Ventura Rivers and Calleguas Creek watersheds report. In order to expedite the revision of the report, no changes have been made in the appendices. Therefore certain discrepancies exist between the report and the appendices.

A comparison of the following tables from the report with comparative tables in the appendices will indicate the major revisions made in the report.

Table 1, report, and Table 15, Appendix III. The tables in the appendix are shown on the basis of 1948 prices, while Table 1 of the report is on the basis of long-term projected prices.

Tables 2 and 3, report, and Tables 1, 2, 4, 5, 6, 7, and 8, Appendix IV. The increases in quantities and costs of the measures shown in the report are due primarily to the inclusion of the total program for the watershed in contrast to the program shown in Tables 2, 4, and 5. The type A and type B measures are shown separately in report Tables 2 and 3, while they are combined in Table 8 of the appendix. The costs shown in the appendix are on the basis of prices prevailing in 1948, while the costs in Tables 2 and 3 are on the basis of long-term projected prices. The estimated Federal costs in Table 3 on non-Federal land differ from those in Table 6, Appendix V, in that they do not include financial assistance by the

Federal Government, such as Agricultural Conservation payments to landowners and operators. Tables 2 and 3 of the report are given on the following pages.

Table 4 and "Comparison of Costs and Benefits," page 12, Appendix V. The figures in this section of the appendix show the benefits in the accelerated program on the basis of 1948 prices, while Table 4 of the report shows the benefits of the total program on the basis of long-term projected prices.

Table 2

Santa Clara-Ventura-Calleguas Creek Watersheds
(Long-Term Projected Prices)

Estimated Cost of Installing Flood-Prevention Measures
(A Measures)

Measures	Unit	Quantity	COST		
			Federal 1/	Non-Fed.	Total
			Dollars		
Stream Channel Impr.					
Federal Land	Mile	6	28,000	-	28,000
Non-Federal Land	Mile	138	5,020,900	1,307,400	6,328,300
TOTAL		144	5,048,900	1,307,400	6,356,300

1/ Includes cost of collecting basic data needed for guiding program installation and operation, and testing effectiveness of the program.

Table 3

Santa Clara-Ventura-Calleguas Creek Watersheds
(Long-term projected prices)

Estimated Cost of Installing Land-Treatment Measures
(B Measures)

Measure	Unit	Quantity	COST			
			Federal	Non-Federal Public	Private*	Total
			---------- D o l l a r s ----------			
Protected Outlets						
Non-Federal Land	Acre	22,700			635,000	635,000
Terraces and Diversion Systems						
Non-Federal Land	Acre	8,700			200,100	200,100
Estab. of Permanent Cover						
Non-Federal Land	Acre	25,800			422,700	422,700
Estab. of Annual Winter Cover Crops						
Non-Federal Land	Acre	4,800			19,700	19,700
Coop. Forest Fire Control						
Non-Federal Land	Acre	450,500	803,700	803,700		1,607,400
Fire Control						
Federal Land	Acre	717,500	2,521,300			2,521,300
Fencing						
Non-Federal Land	Mile	125			60,400	60,400
Federal Land	Mile	125	60,400			60,400
Stock Water Dev.						
Non-Federal Land	No.	50			24,200	24,200
Federal Land	No.	50	24,200			24,200
Range Reseeding						
Non-Federal Land	Acre	5,000			97,100	97,100
Federal Land	Acre	5,000	97,100			97,100
Technical Services Open Land			494,800			494,800
Educational Asst.			21,000	21,000		42,000
TOTAL			4,022,500	824,700	1,459,200	6,306,400

*Combined with Non-Federal Public in Table 3 as shown in the report.

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 1

PHYSICAL FACTORS

Santa Clara and Ventura Rivers and Calleguas Creek

To accompany report on survey, flood control,
Santa Clara and Ventura Rivers and Calleguas Creek, California

APPENDIX 1

PHYSICAL FACTORS

Santa Clara and Ventura Rivers and Calleguas Creek

Physiography

One large and two small watersheds have been combined for this report. The Santa Clara River is the large drainage in the center with the Ventura River to the north and Calleguas Creek to the south. These streams flow into the ocean about 60 miles northwest of Los Angeles. The total area of the combined drainages is 2,158 square miles or 1,381,120 acres. A brief description of each watershed is given below.

The Ventura River is a fan-shaped coastal stream with an area of 228 square miles or 145,920 acres. The drainage has an average width of 11 miles and is about 32 miles in length. The watershed area includes two major physiographic units: (1) The steep, rocky, chaparral-covered Santa Ynez Mountains, which attain a maximum elevation of 6,000 feet at Montecito Peak and descend abruptly to the lower lying Ojai, Upper Ojai, and Santa Ana Valleys; (2) the more rounded coastal hills to the south, averaging about 2,000 feet in elevation and characterized by a grass-oak-sagebrush cover. The Santa Ana and Ojai Valleys occupy elevated positions at the base of the mountains and are not affected by floodwaters from the Ventura River proper. These valleys are subject to more localized floods, however, from Coyote, Stewart, Gridley, Senor, and Horn Creeks. During large floods, debris-laden flows meander across the alluvial cones along the base of the mountains, cross the valley floor, and cause flood and sediment damage en route.

The Santa Clara River heads north of Los Angeles and flows west for approximately 90 miles to the ocean. The area of the watershed is about 1,620 square miles or 1,027,200 acres. Most of the watershed is rough and mountainous land, largely covered with chaparral and sagebrush. Only about 10 percent of the Santa Clara watershed is valley floor and coastal plain. The mountains in the western and most rugged portion are rough and broken and are characterized by long ledges of outcropping rock and precipitous escarpments. The topography is less severe in the north and eastern sections. The highest elevation in the watershed is Mt. Pinos at 8,826 feet. The main tributaries of the Santa Clara River are the Sespe, Piru, Santa Paula, and Castaic Creeks. The Sespe drains the western part of the watershed consisting of the most rugged terrain in the watershed. Piru Creek drains the northwest section consisting of high mountains and semidesert valleys. Castaic Creek drains the north central part of the watershed, an area of low relief with a semidesert climate. Streamflow for the most part is intermittent.

Calleguas Creek watershed has a total area of 325 square miles or 208,000 acres. This watershed is oval in shape, about 30 miles long and 14 miles wide. The topography is moderate with elevations ranging from sea level to 3,600 feet in the headwaters area. The main stream rises in the Santa Susana Mountains. In its course westward it is known as Arroyo Simi, Arroyo Las Posas, and finally Calleguas Creek where it flows through Pleasant Valley and across the Oxnard Plain to the ocean. Conejo Creek is the largest tributary. Calleguas Creek is deeply incised in the sections between basins but within the basin sections flood runoff spreads and causes damage. In the valley sections, save for the Oxnard Plain, alluvium is deep and great gully systems have been built up.

Economic Development

Ventura River Basin 1/.--The 1940 population of the drainage area was between 9,000 and 10,000, of which 55 percent was rural and 45 percent urban. The city of Ventura had a 1950 population of 16,532, of which more than 3,000 reside in that portion of the city which is in the Ventura River basin. The remainder of this city is in the Santa Clara River basin. The only other incorporated city is Ojai which had a population of about 2,500. The growth of population is shown by the following figures for Ventura County:

Year	Population
1890	10,071
1900	14,367
1910	18,347
1920	28,724
1930	54,976
1940	68,883
1950	114,647

The increase between 1920 and 1930 was largely due to the development of an oil field in the basin.

The principal activities of the Ventura River basin are agriculture, the production of petroleum and natural gas, and manufacturing. The production of petroleum and natural gas is by far the most important.

About 11,000 acres are devoted to the growing of citrus and deciduous fruits, nuts, and field crops, of which about 4,000 acres, including the most valuable crops, are irrigated. In the northern part of the basin about 64,000 acres, or 44 percent of the entire drainage basin, are national forest lands which are utilized for recreation and a limited amount of grazing.

1/ Much of the data on economic development has been obtained from survey reports of the Corps of Engineers, Department of the Army.

Santa Clara Basin.--The population of this basin was estimated at 36,000 in 1945. Almost all the population is in the valley area along Santa Clara River and the coastal plain. The Oxnard Plain, which is affected by underground flow and surface floods from the Santa Clara River, is more densely populated than the Santa Clara River drainage area. The total 1945 population of this area is estimated at 55,000. The population of Oxnard increased from about 8,500 in 1940 to about 19,000 in 1945, and the population of Hueneme, a seaport on the Oxnard Plain, increased from about 2,700 in 1940 to about 35,000 (including naval personnel) in 1945. Military activities were chiefly responsible for these increases.

Agriculture and the processing, packing, and shipping of agricultural products are the principal occupations in the basin and on the Oxnard Plain. The petroleum industry is second in importance. The lower alluvial valleys and the coastal plain are highly developed agricultural areas and the upper valleys are used primarily for cattle raising. The mountain area constitutes over 90 percent of the Santa Clara River basin and includes about 1,000 square miles in the Angeles and Los Padres National Forests.

In the Santa Clara basin about 50,000 acres are under cultivation of which 40,000 acres are irrigated; on the Oxnard Plain about 45,000 acres are normally under cultivation of which 40,000 are irrigated. Approximately 90 percent of the water for the 80,000 acres under irrigation is pumped from the underlying water-bearing gravels, the remaining 10 percent used is obtained from stream diversions. The underground water supply is replenished partly by percolation of water from spreading grounds along the Santa Clara River. The average duty of water varies from 0.9 to about 2.3 acre-feet per acre and the average cost of water varies from about $10 an acre-foot in the Santa Clara River valley to about $5 an acre-foot on the coastal plain. Good citrus and walnut land in the Santa Clara River valley between Ventura and Santa Paula is valued at approximately $2,500 an acre. On the Oxnard Plain farm land is valued at $1,200 to $1,500 per acre.

Calleguas Creek Basin.--The 1940 population of this basin was estimated at 10,500, an increase of 50 percent over the 1930 population. The war-time increase in the population of the Oxnard Plain between Calleguas Creek and Santa Clara River has been discussed. Exclusive of the cities on the Oxnard Plain, nearly all inhabitants live in the agricultural areas and 80 percent of the 1940 population was rural.

There are several fruit and walnut packing plants in the basin and a large beet sugar plant at Oxnard. In this basin oil production is a minor industry. Most of the population is engaged in farming or in the preparation of farm products for market.

Approximately 63,000 acres of valley land are under cultivation, of which 37,000 acres are irrigated and 26,000 acres are dry-farmed. These acreages are exclusive of the Oxnard Plain which was described in

connection with the Santa Clara River. About 14,000 acres of hillside land are cultivated, of which only 2,300 acres are irrigated. Part of the hill and mountain areas is used for grazing. From 1916 to 1929 agricultural development reached a peak and extensive tracts of hillside land were brought under irrigation. However, many of the hillside farms were abandoned during the dry period from 1920 to 1932 when the water table lowered and pumping costs increased.

The entire supply of water for the 40,000 acres of irrigated land in the Calleguas Creek basin is pumped from the gravels underlying the valleys. Most of the farms in the basin have their own pumping installations. An extensive drainage system has been installed in one local area which formerly had a high water table.

Many data on the economic development of the report area are on a county basis and cannot be segregated by river basins. Most of Ventura County is included in the three major basins of the report area, hence data from this county are applicable to the report area, also this county contains most of the economic development of the report area.

Ventura County has an area of 1,188,480 acres, of which 553,000 acres are privately owned, and 558,000 acres are national forest. Urban and rural population is about evenly divided. Total income payments to individuals, estimated at $44,756,000 in 1939, rose to $138,892,000 in 1944, a gain of more than 210 percent. Over the same period wages and salaries increased 270 percent. Mineral production, chiefly petroleum and natural gas, was valued at thirty and one-half million dollars in 1944. In the 1947-48 fiscal year the assessed value of property in the county was $160,209,000, or almost double the value ($84,063,000) ten years previously.

The gross value of agricultural production in 1949 was 68 million dollars in round figures, or three times that of 1939 (22 million dollars). Lemons are the most important crop, followed by oranges, beans, walnuts, vegetables, and dairy products. The total number of farms in Ventura County is 2,000 and the average size is 260 acres. The 1949 annual report of the County Agricultural Commissioner gives the value of all farm land as $136,187,000.

Effect of Economic Development on Flood-Control Problems.--Data on economic development of the report area show the remarkable growth in the past decade. While the growth was stimulated by the war-time activity and military installations, the area does not appear to be undergoing a temporary "boom" which may later dissipate. Future growth is on a firmer basis than some other areas which enjoyed a war-time increase in population and activity. In this area the increased development has been more of the nature of a broadening of the region's economic base, from the previous economy which was based primarily on petroleum production and citrus culture. Increased industrial activity, establishment of permanent military installations, more intensive use of presently cropped land and conversion to higher value crops, extension of crops

to the less desirable agricultural land, and the accompanying increase in related service industries are features of the expanding economic development.

The increased development of the area has several effects which are important from the standpoint of flood control and water conservation. One lies in the general increase in potential flood damages due to increased population and the higher values of improvements subject to flooding, over conditions existing and predicted at the time present flood-control structures were planned.

The increase in population has led, in some localities, to the development of residential districts in flood hazard areas. The danger of such occupancy is not apparent in years of low winter flows, leading to continued development and the ultimate creation of a very large damage potential in areas previously considered submarginal and of low value.

The impact of the rapid development has affected nearly all phases of the area's economic pattern--land use, industrial development, transportation lines, water use, recreational facilities, etc. A strain is placed on the areas' service utilities, particularly the domestic and industrial water supply, increasing the necessity for finding new supplies or conserving every bit of the local supply. Aside from future possibilities such as atomic-powered sea water distillation or a regional shifting of surplus runoff from western streams, there are no sources of new water for the report area.

Present agricultural and other water uses have reached the limit of the dependable supply of groundwater available in "dry cycles." Maintenance of the present economy of the area depends upon additional water supplies, which as mentioned, can only be obtained by conserving the local supply through construction of storage reservoirs. This stage in the area's development has now started. While reservoir sites exist, their construction will be costly and their life will be short unless the present high rates of sedimentation are reduced.

The pressure of population increase in southern California has led to the clearing and planting of land, especially in the eastern end of the Santa Clara drainage, which has doubtful promise as cropland. Unless carefully handled under proper conservation methods these areas could become sources of high sediment production. The scattered extension of occupancy to the margin of the wildlands increases the fire hazard to the brush-covered mountains which are the source of the region's water.

As would be expected, the increased population has led to the greater recreational use of the mountainous areas with consequent increase in the fire risk to the watershed cover. The increased use in the past few years and the indicated trend for the future, unless matched by an increase in the prevention effort, will result in a greater number of fires.

Climate

The Santa Clara climate is characterized by cool moist winds from the ocean that have a moderating effect upon the climate. The typical seasons are long dry summers and short wet winters. Frosts are rare in the coastal region but common in the inland and mountain regions. The recorded extremes of temperature at Oxnard, on the coastal plain to the west, are 104° F. and 26° F. The seasonal and diurnal range of temperatures is much greater inland. At San Fernando, to the east of Calleguas Creek, the recorded extremes are 113° F. and 23° F. The prevailing winds, which are from the Pacific Ocean, are of light to moderate velocity; the highest velocities normally occurring in the spring. About 75 percent of the annual precipitation occurs from December to March, inclusive. Mean seasonal precipitation varies from about 8 inches in the eastern valley areas to about 40 inches in the Topatopa Mountains and is about 14 inches along the coast. Snow normally covers the higher peaks in the winter but it is not an important factor in contributing to the flood problem.

Geology

Within the Ventura watershed the formations vary in age from the upper Cretaceous to the lower Pliocene. The exposed rock is of sedimentary origin and in most cases is soft and easily eroded. These sediments, since their deposition, have been elevated, accompanied by some folding and faulting, so that rock outcrop exposures show the bedding to be steeply inclined and in some cases overturned. The general strike is east and west and dips to the south so that the oldest formation is at the northern boundary. All of these formations are well-cemented and interbedded sandstones, shales, and conglomerates. Scattered throughout the area are relatively pervious Terrace deposits (late Pleistocene). Along the beds of the principal streams are found deposits of Recent alluvium. Most of the commercial wells are in this formation. Lines of topographic expression suggest a number of faults in the area.

The Santa Clara basin is underlain by an impervious basement complex of pre-Jurassic schist, quartzite, slate, granite, and limestone. In large sections these rocks are exposed, principally in the area north of the Topatopa Mountains and south of Soledad Canyon in the San Gabriel

Mountains. Most of the basement complex is overlain by friable sandstones, conglomerates, and shales, laid down during the Tertiary and Quaternary periods. These rocks are exposed over large portions of the mountains and foothills. Volcanic rocks of Miocene age outcrop north of the Topatopa Mountains and along Soledad Canyon and to the north. The alluvial deposits are very deep exceeding 1,000 feet in some places. This fill forms an aquifer from which water is pumped for agricultural, industrial, and domestic use. In general, the sedimentary formations of the lower watershed are of marine origin and the upper portions are of non-marine origin.

The Calleguas watershed is also underlain by a basement complex of pre-Jurassic crystalline rocks. It differs from the Santa Clara basin in that they are not exposed in the Calleguas Creek area. The more recent formations consist of Cretaceous sandstones and shales, Tertiary shales, sandstones and conglomerates, and unconsolidated Quaternary alluvium and terrace deposits. Igneous rocks outcrop only in the southwestern portion of the area. Excepting a few beds of Tertiary conglomerates and sandstone, the bedrock of the area is relatively impervious to water. The valley portions of the basin constitute a valley fill exceeding 1,000 feet in depth in portions of the area.

Drainage Characteristics

Continuous flow throughout the length of the channel in the Santa Clara group is evident only during the rainy season and in some instances only during periods of flood flows. The flow of tributary streams is for the most part intermittent in character. In many instances the valley fill over which the streams flow absorbs most of the water prior to the time it joins the main river. In flood the mountain reaches of the streams are heavily laden with debris. On leaving the steep mountain canyons they lose their transporting power and the load of debris is dropped, save for the fine material which is moved farther downstream with each flow and eventually delivered to the ocean. Spreading works have been developed to aid percolation into the underground acquifer.

All streams in the valley portions appear to be aggrading. The flow from large storms degrades the channels but the large number of small storms offsets the occasional scouring. The net result is apparent gradual aggradation.

Ground Water

The streams of the Santa Clara group have produced great natural aquifer by filling the bedrock basins with material eroded from the surrounding mountain areas. The major portion of the recharge of the Oxnard Plain, which is pumped heavily, comes from the Santa Clara River. Fifty-five to 60 percent of the total discharge of the Santa Clara comes from two of its tributaries, namely, Piru and Sespe Creeks. The draft upon this underground basin for irrigation water has increased greatly. 2/ Between

2/ Report on water supply--Santa Clara Water Conservation District, 1947. Conkling.

1944 and 1946 there was a 70 percent increase in draft. This increased use has been brought about by an increase in the acreage of irrigated crops and the introduction of crops requiring more water for growth and maturity.

Records of precipitation and discharge indicate a great cyclical variation. During wet cycles the supply of water for all uses is adequate. However, during dry cycles the demand will exceed the supply. The following tabulation illustrates the variation in discharge from Sespe and Piru Creeks:

Years	Length of period	Average annual discharge
	Years	
1894-1904	11	58 percent less than long-time average
1905-1918	14	45 percent more " " " "
1919-1936	18	35 percent less " " " "
1923-1936	14	49 percent less " " " "
1937-1944	8	79 percent more " " " "
1945-1947	3	Discharge less than long-time average indicating the probability of the beginning of a new cycle.

Recent studies indicate that there will be no serious permanent overdraft above the Montalvo basin. The shortage will occur in the Oxnard Plain below Montalvo. During a cyclical drought such as occurred in the 14-year period, 1923-36, it is estimated that the average annual recharge of the coastal plain basin by the Santa Clara River would total 25,000 acre-feet. Other sources, small streams and precipitation on the valley floor, would contribute about 5,000 acre-feet. Thus, the expected recharge rate for the basin would be 30,000 acre-feet annually. The present total average annual demand is 60,000 acre-feet. In 1947, there was an overdraft of about 30,000 acre-feet in the Oxnard Plain and the portion of Pleasant Valley dependent on the Oxnard Plain. The most recent estimate indicates 30,000 acre-feet as the average annual decrease in ground water under present drought conditions.

Attempts to correct this overdraft have to date been confined largely to the construction and operation of spreading grounds. During the period 1929 to 1939 the Santa Clara Water Conservation District has spread a total of 165,688 acre-feet. The average annual quantity of water placed in the aquifer by spreading during this period was 16,560 acre-feet. Spreading grounds are located along Piru Creek near Piru, along Santa Paula Creek near Santa Paula, and south of Santa Clara River just below South Mountain. The total capacity of these spreading works is about 230 cubic feet per second.

Consideration and study have been given to the possibility of impounding water in reservoirs for use during the rainless season. Several

reservoir sites on Piru and Sespe Creeks have been considered. In 1949 a county agency completed construction of a water-conservation reservoir on Matilija Creek, a tributary of the Ventura River, as a first step in providing additional water to meet the growing requirements of the Ventura River area. At the same time studies were under way leading to construction of the second step, a reservoir on Coyote Creek, another tributary of Ventura River. Cooperative field and office studies of this reservoir are being made by the Ventura County Flood Control District, the State Water Resources Board, and the State Department of Public Works.

The studies have progressed to the point where construction can be started when final details have been decided. The capital costs of the Coyote Creek reservoir have been estimated by the State Water Resources Board at $9,189,000 and $18,438,000 (1951 prices) for the two sizes of reservoir considered. The corresponding capital costs per acre-foot of net seasonal safe yield would be $660 and $840.

The cooperative studies mentioned have also been extended to cover the possibilities for developing and utilizing all local water resources to meet the present and future needs of the entire county. At present, dam site conditions are being explored by field parties and the many previous water supply studies are being reviewed.

In general it can be stated that water storage in reservoirs is costly in the Santa Clara stream group. This high cost is caused by the cyclical nature of the rainfall. This necessitates the construction of large enough reservoirs to carry over during dry cycles and emphasizes the importance of preventing reservoir storage space loss by sedimentation.

Soils

The soils of the watershed have been separated into two groups, based upon topography and land use--mountain soils and valley soils.

A. Mountain Soils.-- The residual soils for the most part are shallow, unproductive, and nonagricultural. They occupy the steep rugged mountain areas. The soils formed from the semi-and unconsolidated sediments are subject to severe erosion when the vegetative cover is removed. In certain areas geologic or normal erosion is very active, especially the soils derived from granite. The soils derived from the metamorphics are less subject to a high normal rate of geologic erosion. The mountain soils were formerly classified as "rough, stony land" by the Bureau of Chemistry and Soils. Recently the soils within the National Forest boundaries have been reclassified, described, and mapped according to geologic origin. See table 1.

Table 1. Characteristics of watershed soil groups in the Santa Clara and Ventura basins 1/

Soil Group	Geologic formation	Soil age	Percent of total mountain area	Soil depth: Average	Soil depth: Range	Water storage 4/: WP 2/	Water storage 4/: WP to FC	Water storage 4/: FC to sat. 3/	Permeability	Erodibility	Substratum: Permeability	Substratum: Porosity
				Feet	Feet	Inches	Inches	Inches				
Wilson	Acidic intrusives, diorite, Lowe granodiorite, monzonite	Recent	18.9	½	0-2	.2	.2	2.0	High	High	Low	Low
Violin	Consolidated conglomerates, sandstones, shales	Recent	51.5	2	1-3	3.4	3.4	1.6	Moderate	Moderate	Moderate to high	Moderate to high
San Gabriel	San Gabriel formation, metamorphic complex	Recent	3.5	3	0-8	1.2	1.5	12.4	High	High when exposed	Moderate	Low to moderate
Compromise	Igneous and metamorphic basement complex, well mixed	Recent	1.9	1	0-3	.6	1.2	3.2	High	High	Low	Low
Castaic	Poorly consolidated sediments, mostly sandstones	Recent	11.2	1	0-2	.6	1.2	3.2	High	Moderate	Very high	Very high
Terrace	Quaternary terraces (unconsolidated and gravelly)	Immature	2.4	4	3-6	7	7	6.5	Medium to low	High when exposed	Very high	Very high

Continued

Table 1. Characteristics of watershed soil groups in the Santa Clara and Ventura basins 1/ - Cont'd.

Soil group	Geologic formation	Soil age	Percent of total mountain area	Soil depth		Water storage 4/			Permeability	Erodibility	Substratum	
				Average	Range	WP 2/	WP to FC	FC to sat. 3/			Permeability	Porosity
				Feet	Feet	Inches	Inches	Inches				
Riverwash	Riverbed, flood plain, recent alluvium	Recent	3.1	--	--	.4	.5	4.0	High (infiltration rate low if water table high)	Low	Very high	Very high
Mill Creek	Anorthosite	Recent	1.9	$\frac{1}{4}$	0-$\frac{1}{2}$	.1	.1	.8	High (limited by soil depth)	Very high	Low	Low
Bouquet	Pelona schist	Recent	4.6	2	1-3	1.2	1.2	3.2	High	Low	Low to moderate	Low to moderate
Johnstone	Tertiary volcanics (andesite and basalt)	Young	1.0	4	2-8	6.8	6.8	6.4	Low to medium	Moderate	Low to moderate	Low to moderate

1/ E. A. Colman, Cal. Forest and Range Expt. Station, 1945.
2/ Wilting point.
3/ Field capacity to pore space saturation.
4/ Water storage values are for the average soil depth, except for Riverwash which is in inches per foot of depth.

B. Agricultural Soils.--Agricultural soils have been described, mapped, and classified by the Bureau of Chemistry and Soils in a published report on the Ventura area in 1917. This report covers a major portion of the agricultural land in the area. The Soil Conservation Service has completed a more detailed study of portions of the valley and foothill soils of the basin. The more important soils are grouped in accordance with origin.

Residual soils are mainly identified with the hilly and mountainous regions. The soils derived from the sedimentary rocks are moderately extensive. The surface is rolling, hilly, or mountainous, with small areas of rock outcrop in places. The soils are well to excessively drained, however, they are retentive of moisture where they are sufficiently deep. The soils are retentive of moisture if well handled, but the heavier soil types crack and dry out badly when undisturbed. Soils derived from igneous rocks are relatively high in organic matter. They are frequently hard and compact, and the heavier phases usually have an adobe structure. Typically the topography is hilly, rolling, or mountainous, with some areas of rock outcrop. This series also has good drainage.

The old valley-filling and coastal plain group are old, unconsolidated, waterlaid deposits which have undergone marked change in their subsoil and topographic features since deposition. The organic matter content is usually high in types of heavy texture but lower in those of light texture. They occur in very hilly or rolling areas on smooth or eroded marine or stream terraces, or on the sloping remnants of old alluvial fans. These old alluvial fans have either been elevated since their deposition or have been left in their present positions by the cutting of deeper stream channels through them. These soils usually are intermediate in elevation between the residual and recent alluvial soils. In contrast with the recent alluvial soils they are undergoing active erosion or are being covered with recent alluvial material.

The recent alluvial soils make up this group. They consist of soils derived from sediments that have not undergone material changes or internal modification since their deposition. They are still in the process of formation.

This is the most extensive group in the area. They cover the Oxnard Plain and occur also as river bottom deposits and as numerous alluvial fans in the main stream valleys at the mouths of tributary drainages. In a portion of the smaller valleys no distinct bottom lands are present, the valley being composed of numerous small fans that were formed by the side drainage ways. These soils are formed from various materials washed from the areas of sandstone, shale, conglomerate, basic igneous rocks, and old valley filling deposits. These soils are characterized by permeable surface soils and subsoils which are moderately retentive of moisture. They are usually well-drained and productive but

injurious quantities of alkali occur naturally near the ocean where the water table is near the surface. This alkali condition has been overcome on most of the areas where it originally occurred by a process of artificial leaching. Stratified subsoils are common in the soils of this group with this characteristic most pronounced in the valley bottoms and on the broad, sloping fans.

Three miscellaneous kinds of soil occupy a minor portion of the area and are unimportant agriculturally and are used mainly for pasture. Namely, they are (a) Riverwash, (b) Coastal beach and dunesand, and (c) tidal marsh. These three cover only a few square miles on the lower parts of the valley floors.

Natural Vegetative Cover

Native vegetation has probably been modified by man's use of the basin. It is impossible to indicate accurately the original undisturbed condition. However, early records indicate that with the establishment of the Mexican regime, fires increased in severity and that ranges were quickly overstocked. From 1860 to 1900 the livestock population, except during drought years, was high. Damaging overuse was the rule rather than the exception. During this era newspaper accounts frequently reported great fires that were set because it was the belief that this treatment of the watershed would increase the quantity of forage. Creation of the Reserves and later the present National Forest system was the first attempt at organized fire control and grazing regulation. Not until the Civilian Conservation Corps was inaugurated in 1933 was fire control fairly effective.

As a result of this early abuse of the vegetative cover it has been modified in many respects. The conifer, woodland, and mixed chaparral types have been pushed back. There is a marked tendency for many of the most valuable litter-building species to decrease with repeated burnings, invariably resulting in deterioration of both the cover and the site. Probably the coniferous type has suffered the greatest areal loss. Deterioration of the chaparral is reflected largely in a lowering of the height and a decrease in the density of the stand.

In the following table the acreage of the various cover types is shown.

Table 2. Native cover of the uncultivated land of the Santa Clara group

Vegetative cover type	Area in acres Ventura	Santa Clara	Calleguas	Total area Acres	Percent
Barren and semibarren	1,587	23,040	--	24,627	2.06
Grasslands and grass woodland	6,361	51,840	28,672	86,873	7.22
Sagebrush	8,966	213,760	59,200	281,926	23.70
Chaparral	97,485	528,640	17,090	643,215	54.03
Woodland	5,926	11,520	--	17,446	1.36
Pinon and juniper	--	87,680	--	87,680	7.35
Coniferous forest	--	50,560	--	50,560	4.28
Total	120,325	967,040	104,962	1,192,327	100.00

The barren and semibarren areas are composed of broad sandy river wash areas and portions of the mountains that do not have sufficient soil to support a dense enough stand of native vegetation to be classed in some other category.

The grass and grass woodland types consist of some broad-leaved trees and digger pine with annuals filling the interspaces. The dominant annual species are wild oats, brome grasses, fescues, and alfileria. The common trees are blue oak, California valley oak, Alvord oak, coast live oak, and digger pine.

The sagebrush type is an open association containing sages, sagebrushes, or other woody plants of similar character and restricted in this area to the upper Sonoran Life zone. In many places it appears to be a pioneer type occupying the comparatively raw soils of washes and eroded slopes. Plants characteristic of this type commonly produce very little litter. In general, the dominant species vary from 2 to 4 feet in height.

In the chaparral type, the portions of this type characterized by the dominance of chamise, the height normally ranges from 3 to 8 feet. Litter is thin and this reduces its effectiveness in controlling run-off. Where oak and manzanita are dominant the litter is deeper; the height range is from 4 to 12 feet. Because of its greater density and better rate of litter production the oak and manzanita dominated portions of the chaparral type form a superior watershed cover.

The woodland type is composed of various broad-leaved trees. Normally, a closed canopy is approached or formed. Two classes of sub-types occur. The first, found either on north slopes or in canyons, is characterized by the dominance of either California laurel or coast live oak. The second sub-type is restricted to canyon bottoms and such dominants as alder, sycamore, cottonwood, oak, and California laurel occur. The

woodland type is important from both the recreational and watershed standpoints.

The pinon and juniper types are dominated, either individually or together by stands of single-leaf pinon pine and California juniper. The trees are usually open-spaced and in association with the local sagebrush, chaparral, or herbaceous plants and in many cases blue oak and Alvord oak. Generally, in juniper sagebrush associations, the sagebrush species are dominant.

The coniferous forest areas occupy the highest elevations and are usually dominated by big-cone spruce. From the evidence of scattered individuals and standing dead trees it seems apparent that this type has been replaced by chaparral in many areas. The surviving remnants generally occur where they have been afforded natural protection from fire, such as on rocky slopes.

Flood and Erosion Sources and Problems: Wildlands

The principal flood sources can be segregated into two broad areas--the mountainous wildlands occupying 90 percent of the basin and the agricultrual lands of the valleys and lower foothills. Floods originate on the wildlands, as they receive at least 95 percent of the precipitation. For the most part the cover can be rated only fair, having deteriorated during the past century due to fires, overgrazing, cultivation, and urban road and oil field development. In the eastern portion arid and semiarid conditions, plus recurrent fires, have apparently caused serious site deterioration. This retards the naturally rather slow rate of plant recovery.

No accurate record of the condition of the watershed in its primitive condition exists. However, such records as are available indicate that great change has taken place. Under primitive conditions reasonable equilibrium existed between precipitation, vegetation, and soil. Evidence of recently accelerated erosion is to be found in the boulder-strewn channels, and the presence of broad sand- and gravel-choked stream beds and large, raw gullies. The erosion rate at the present time is relatively high, ranging from about 700 to 5,200 cubic yards per square mile per year.

The most notable characteristic of the Santa Clara group of streams is that the stream beds are filled with sand from the very headwaters. Consequently, when heavy precipitation falls the torrential flows are bulked by debris and then meander across the high valleys and spill into the main drainages. The result is that land and physical improvements are damaged along the entire length of the streams.

The major problem in the wildlands area is the maintenance and improvement of the vegetative cover and control of large quantities of debris available in the channels. Destruction of plant cover and ground litter

by fire exposes watershed slopes to the full impact of heavy rains. Repeated fires and the erosion that follows bring about progressive site deterioration which is reflected in accelerated runoff and erosion rates. Protection from fire alone will not bring about the desired reduction in floodwater and sediment damages. Revegetation of active sediment-producing areas to native vegetation suitable to the site is required where vegetation is lacking or is very sparse. Improved range management is needed to secure increased density of plant cover, reduce the effect of trampling, and increase the infiltration capacity of the soil.

The high rate of sedimentation seriously affects the economics of reservoir construction. Channel stabilization is needed in certain areas to control huge quantities of debris that are now in transit in the channels and to stabilize channel side slopes in order that vegetation may become established and thus restrain further erosion. Oil-field development, with total disregard of the need for soil stabilization, has contributed materially to abnormal rates of erosion and runoff. Road and highway construction is adding to the problem by creating erodible fill and overcast slopes and uncontrolled surface drainage. All of these combine to create problems difficult to control.

Flood and Erosion Sources and Problems: Agricultural Lands

Flood and sediment problems in the valley and foothill agricultural areas arise from accelerated erosion on the watershed agricultural lands and wildlands and/or inadequate water courses on the streams, minor tributaries, and farms. Primary sources in agricultural areas are lands not suitable for continuous cultivation and from stream channel erosion in the deep valley fill. More intensive development of rural areas will inevitably create flood problems and require controls not anticipated at this time.

In several instances local flood-protection districts have been organized to cope with specific problems. However, their resources have been too limited for very complete controls. The recently organized Ventura County Flood Control District provides a medium for prosecution of local improvements within its resources.

Flood damage on Calleguas Creek upstream from Camarillo is primarily concerned with streambank cutting and resultant loss of valuable agricultural land. Downstream from Camarillo on the Oxnard Plain, the problem is one of sedimentation of all stream channels. The source of sediment of lower Calleguas Creek is primarily and equally from streambank cutting and sheet erosion of agricultural land in Calleguas Creek waterhsed above Camarillo. Substantial floodwater and sediment damage occurs in tributaries throughout the watershed. 2/

1/ Carl B. Brown and George W. Collier. Soil and water conservation research needs in the Simi Valley and adjacent areas, Ventura, California.

Las Posas drains into Calleguas Creek through Revelon Slough. Floodwater and sedimentation damage to agriculture and improvements occurs in the vicinity of discharge of Las Posas wash onto the Oxnard Plain. Water flows overland for two miles before being picked up by the Revelon Slough drainage system. The source of sediment is the Las Posas area. Sheet and gully erosion both supply material. Much sheet erosion results from improper land use. Gullies are deeply entrenched in alluvium and are active sources of sediment except in gully reaches stabilized during operation of a Soil Conservation Service demonstration project. Local scour and deposition occur within the Las Posas area from uncontrolled concentration of tributary flow.

Frequent damage to agriculture and roads by water and sediment occurs along Del Norte and Santa Clara Avenue in the north part of the Oxnard Plain near South Mountain. The sources of sediment are in the extreme west part of the Las Posas area and gully erosion adjacent to South Mountain. As in the case of Las Posas wash, no defined channel section exists in the Oxnard Plain between the hills and Revelon Slough, a distance of about four miles.

Lack of channel definition in the local drainage area immediately south of and paralleling Las Posas Road near Camarillo is the cause of a problem involving both scour and sedimentation of agricultural land. Water and sediment flow from the Camarillo hills through defined gully sections to Las Posas Road.

In the Santa Clara River valley flood damage in agricultural areas from small tributary streams and local runoff occurs primarily in the valley lands between the Santa Clara River and hills to the north.

Between Ventura and Santa Paula these valley lands are largely planted to citrus, walnuts, and beans. Soils are of medium and heavy texture producing relatively high rates of local runoff. Runoff from the hills on the north passes through the area in entrenched gullies near the hills, which decrease in size to inadequate sections near the river. Flood problems arise from concentration of local runoff on the agricultural valley slopes, bank cutting in the gully or barranca reaches, and sediment or floodwater damage adjacent to lower stream sections approaching the Santa Clara River.

East of Santa Paula tributary streams issue from hills of relatively unstable geologic formation. Stream sections are poorly defined on the alluvial slopes. Citrus development on these areas as far east as Piru are subject to characteristic flood hazards of sedimentation and shifting stream courses.

East of Piru agricultural lands in the watershed generally occur as small areas of deep alluvial valley soils along the Santa Clara River or larger tributaries. Practically all have a problem of streambank cutting or stream overflow. Most of the irrigable land is very productive and is intensively farmed to truck and field crops. This watershed area,

largely within Los Angeles County, is all within the Quail Lake and Upper Santa Clara Soil Conservation Districts.

Bordering the river on the south side is the Bardsdale area. This is largely developed to citrus. Local runoff disposal facilities are well developed in part of the area. Other sections are subject to sedimentation damage from Grimes Canyon and flows from smaller canyons.

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 2

HYDROLOGIC ANALYSIS OF THE FLOOD PROBLEM

Santa Clara and Ventura Rivers and Calleguas Creek

To accompany report on survey, flood control,
Santa Clara and Ventura Rivers and Calleguas Creek, California

APPENDIX 2

HYDROLOGIC ANALYSIS OF THE FLOOD PROBLEM

Santa Clara and Ventura Rivers and Calleguas Creek

In the development and evaluation of flood prevention and control activities, information on the size and number of floods to be expected is required. Of equal importance, however, is a development of methods for estimating the effects of flood-control measures on flood size. Past floods and past storms furnish the chief clue to both the size and number of future floods that may be expected. To obtain the effects of flood-control measures on future floods, a determination is made of the physical differences in watersheds which will be produced by these measures. Then tests are made of what effects such physical differences have produced in past floods and sedimentation from watersheds.

The major subdivisions of the flood problem in these watersheds are 1) the determination of the frequency of peak discharges at damage points in the watershed, and 2) the determination of the sediment delivery at damage and water use points in the watershed.

FREQUENCY OF PEAK DISCHARGES

If flood discharges from a watershed had been measured for several hundred years, and if watershed conditions remained static, then the frequency of expected discharges could be readily determined. However, watershed conditions have been changing and are continuing to change. Discharge records are short and have been measured under varying watershed conditions. Therefore, it has been necessary to study flood "causes" to determine how meteorological events combine to produce discharges, and how watershed conditions and changes in watershed conditions affect discharges. The results of these studies permit extension and adjustment of past short-term discharge records before making estimates of discharge frequency and provide a basis for estimating the changes that flood-control measures will bring about in future flood frequencies.

The particular discharge event whose frequency is needed is often the peak or maximum discharge. If frequency of peak discharges can be determined, average annual damages may be estimated. If the effect of land management or other flood-control measures on discharges can be evaluated, the reduction in damages resulting from a proposed flood-control program may be assessed.

Flood causes may be grouped into two broad categories: the precipitation characteristics and the physical characteristics of the watershed which govern the disposition of the precipitation.

Precipitation Characteristics.--Most of the storms in this region are associated with the extra-tropical cyclones of North Pacific origin.

During the winter months these storms move south over the ocean, being warmed and picking up moisture en route until they are forced landwardd by the Pacific high pressure zone. As the storms reach land they meet the cold air masses and the mountains which force the moisture-laden air to rise and produce torrential precipitation over much of southern California. Occasionally local thunderstorms which produce high intensities occur both in connection with the general winter storms and independent of them.

Most of the precipitation received in the drainage is in the form of rain. Some snowfall occurs in the high mountains, but snow melt in this area is generally considered to have little effect upon the flood flows of the main drainage system.

The distribution of the precipitation throughout both long- and short-term periods influences floods. The short-time intensities of precipitation are critical elements in influencing the magnitude of the peak discharge of the individual flood. At the other extreme, the long-time cycles of precipitation influence seasonal runoff and the frequency of flood events. In this area the average annual precipitation varies widely with elevation and geographic position. Mean seasonal precipitation varies from 8 inches in the valley at the eastern boundary of the Santa Clara drainage to about 14 to 16 inches on the coastal plains and to 40 inches in the higher mountains. For individual years the precipitation has varied from as little as one-fourth to as much as two times the average annual. Pronounced cycles of wetness and dryness are indicated by the ten-year moving average of the annual wetness as shown in figure 1. (Figures and tables are located at the end of the appendix.)

The distribution of precipitation by seasons within each year varies widely. During the summer time measurable precipitation is rare since the Pacific high pressure zone moves inland over the southwestern United States, effectively deflecting storms from this area. Consequently, about 90 percent of the annual precipitation occurs during the six-month period from November to April.

The amount of high intensity precipitation and the wetness of the watershed are of primary importance in influencing the size of floods. These factors may be characterized respectively by the maximum 1-day precipitation and by the 21-day antecedent precipitation to a storm. The distribution of these events for a 69-year period in a nearby watershed, Big Santa Anita, near Los Angeles, is given in table 1. These storm precipitation events with their associated watershed wetness may be considered the primary meteorological causes of past floods. For a given meteorological event the size of the flood has been wholly dependent on the characteristics of the watershed upon which the precipitation fell.

<u>Watershed Characteristics</u>.--Watershed characteristics influencing flood problems vary both in space and time. These variations provide a basis for evaluation of the effects of watershed characteristics on floods.

The geologic types and their associated soils and the vegetation cover and associated land use are two major watershed characteristics which may influence floods. Geology in the area is highly variable between watersheds whereas vegetation cover is highly variable both between watersheds and in time within a single watershed.

The geologic types range from highly erodible unconsolidated and semi-consolidated sediments to hard indurated sedimentary, metamorphic, and granitic rocks. These formations have been complexely folded and broken by several east-west faults. The rugged relief of the mountain areas reflects this folded and broken condition. Alluvial deposits make up the valley areas. (More details of the geology and soils are given in section on erodibility and table 10.)

The vegetation which the soils support is characterized by types which are able to withstand, in various ways, recurrent fires and various degrees of soil and atmospheric drought. The types range from annual grasses in the lower areas to dense chaparral and conifers on the mountain slopes where water is available and to near desert types where precipitation is light. Thus, areal variation in cover density is high.

Even within a single rainfall zone individual tributary watersheds may vary in cover density. Field examination indicates that the existing cover types even at full age develop maximum densities ranging from 44 to 60 percent for whole watersheds. Similarly, within individual tributary drainages, greater variation is apparent as the result of fire. In many areas fire has reduced cover density to zero over large areas of individual watersheds. In recent years, fire alone has been responsible for modifying the average cover density within single watersheds from a low of about 2 percent to a high of 60 percent. Past variations and their effects have been taken into account in evaluating flood-control needs, since these variations provide a basis for evaluating the influence of watershed characteristics on runoff.

Runoff.--General descriptions of floods on the Santa Clara River date back to 1811. These data indicate that since that year five great floods and thirty medium and large-sized floods were experienced on the Santa Clara River. The greatest flood probably occurred in 1862 while other large floods with discharges over 100,000 c.f.s. happened in 1811, 1825, 1884, 1913, 1914, and 1938. The 1938 flood was estimated to have had a peak discharge of 115,000 c.f.s. near its mouth. Because of similar hydrologic conditions the flood history on the Ventura River has probably been very much the same as that of the Santa Clara River.

The peak discharge records for the streams in these basins are rather fragmentary--about 14 gaging stations have been operated at various times. The longest record of peak discharges is for Sespe Creek from which the maximum yearly peak discharges have been reported since 1923. The majority of the stations have been operating only since about 1927. The maximum recorded peak discharges and other pertinent data for a few representative gaging points are given in table 2.

Since peak discharge records were short and the past watershed conditions under which the discharges were measured were highly variable, the need for extending the period of discharge records and adjusting the discharges to some comparable basis before estimating flood frequency is apparent.

Method of Obtaining Peak Discharge Frequencies.--The basic need for determination of peak frequency from a watershed is a long record of discharges for a constant watershed condition. The long record is obtained by: 1) using the short record to determine the relation of peak discharges to precipitation characteristics of the storms causing the discharge; 2) then extending the record to equal the period of the long-term precipitation record by using the relationship found in 1) above.

Estimated discharges for a constant comparable watershed condition are obtained by adjusting the measured discharges for the differences between the watershed cover at the time the discharge was measured and the cover under some standard condition. The magnitude of adjustment needed is obtained by: 1) determining in quantitative terms how differences in watershed conditions in the past affected the magnitudes of discharges; 2) then adjusting each discharge to its expected value under some assigned constant watershed condition. The same basis of adjustment is applied to determine how flood-control measures which influence watershed conditions will affect discharges.

A determination was made of how storm magnitudes, watershed wetness, and watershed cover conditions combine to produce stream peak discharges. The following steps were involved:

1. For the period when discharge measurements were available and watershed cover density could be determined, 23 storms were selected to give representative coverage of storm sizes on wet, moderately wet, and dry watersheds. A storm was defined as a period of precipitation unbroken by lapses of greater than 24 hours and with a total precipitation of 0.02 inch or more.

2. Twenty-nine watersheds ranging in area from one to 202 square miles were chosen so as to represent as wide a range in conditions as possible. The watersheds were located in the nearby San Gabriel-San Bernardino Mountains.

3. For those storms and those watersheds for which the best rainfall data were available 127 storm-watershed data were compiled.

   a. The maximum 24-hour precipitation during each storm on each watershed was determined from available precipitation measurements. The maximum 24-hour precipitation was taken to represent storm intensity.

   b. The precipitation occurring in the 21 days antecedent to the storm maximum 24-hour precipitation was taken as an index of watershed wetness.

c. The average cover density on each watershed during each storm was determined by applying the relationships of cover density to cover type, cover age, and geology, as developed by J. S. Horton, U. S. Forest Service, and summarized in table 6 so that the relationships may be reproduced. Fire history compilations by areas of cover types and geology had been prepared and were available at San Dimas Experimental Forest for most of the watersheds. The average cover density on a watershed was then merely the area weighted average of the cover densities read from the appropriate growth curves of table 6 for the particular cover ages on the watershed at the time of the storm.

4. The storm and watershed characteristics were expressed quantitatively as variables and the associated peak discharge was tallied.

5. The relation of the measured peak discharges from the watersheds for the storms to the storm and watershed variables was determined by multiple regression analysis.

Regression Results.--The relation of peak discharge from watersheds to the two precipitation variables, watershed area and watershed cover density, is given by equation (a), table 3. For definition of variables see table 4. All variables were significant at the 1 percent level. In order to test for possible distortion in the logarithmic function employed, tests were made of the joint relationship between 24-hour precipitation and cover density, between 24-hour and 21-day antecedent precipitation, and between watershed area and cover. None of these was significant. The functions as determined were used in extending discharge records on the basis of the long-term precipitation records and in evaluating cover effects on discharges.

Extension of Discharge Records.--The method of extension is given here for the Big Santa Anita watershed which in turn may be used to extend the records for other watersheds by correlation of discharges. Big Santa Anita had a precipitation station on Mt. Wilson at the head of the watershed for 30 years and only minor changes in cover density during the period. The 30-year record of precipitation at Mt. Wilson was extended to a 69-year record by correlation of precipitation with Los Angeles. The resulting 69-year record of maximum 24-hour and antecedent 21-day precipitation for Big Santa Anita is given in table 1.

Having an extended precipitation record, the frequency of peak discharges was obtained in four steps, as follows:

1. Equation (a) was used to calculate the peak discharges for all of the storms of the long-time precipitation record given in table 1. (The actual storm sizes were used for the large events and the means of the groups of table 1 for the small events.)

2. Observed discharges for Big Santa Anita were tallied. As Big Santa Anita had not been burned since 1910, no adjustments in discharges for

cover changes were necessary.

3. For all storms occurring during the period of discharge record (October 1, 1916, to April 30, 1946) the calculated discharge was plotted against the observed discharge for the storm (see figure 2).

4. On the basis of the trend line of figure 2, the calculated discharges for the period of no observed discharges (October 29, 1877, to September 30, 1916) were corrected.

The 30 years of observed peak discharges plus the 39 years of corrected calculated peak discharges constituted an estimate of discharges for the 69-year period for 40-year-old cover from which the frequency was obtained.

From the standpoint of discharge frequency, the relation established in figure 2 constituted a correction of the calculated discharges for nearly all the individual characteristics of the watershed that affected the discharges. That is, the discharges are corrected for the effects of the geology, shape, and other physiographic features of the watershed, for errors in measuring watershed precipitation, and for snow effects. Although there is considerable dispersion about the trend line of figure 2, still the estimate of the frequency for this short period is good. One method of showing this is by comparing the frequency of the observed discharges and the frequency of the corrected calculated discharges for the same period (see figure 3). The comparison is favorable; so the extended 69-year record of peak discharges, both maximum yearly and all events, for Big Santa Anita were arranged and plotted by the method of Hazen (1930) to give the frequency curves (figure 4). The discharge points may be used in other plotting formulas if desired.

To determine the long-time frequency of peak discharges for other watersheds that had some peak-discharge records the method could have been repeated. However, if the watershed experienced in general the same storms as Big Santa Anita the method could be greatly shortened by taking advantage of correlation between discharges of watersheds when all discharges are on a comparable basis of watershed condition.

The cover density relation to discharge found in equation (a), table 3, provided a basis for adjusting discharges to a comparable basis. However, before making such applications of the findings it was thought desirable to test the cover effects.

<u>Test of Cover Effects for Different Geology</u>.--Equation (a), table 3, was developed for areas where igneous and metamorphic rocks dominated; whereas in some of the watersheds in the Santa Clara and Ventura watersheds marine sediments were most abundant. A test of the cover effect on a watershed, where marine sediments dominated and wide variation in cover occurred, was possible by using peak inflow measurements into the nearby Gibraltar reservoir. For the period 1932 to 1947 peak inflows have been determined. During this period the average cover density on the watershed varied from as little as 27.6 percent in 1934 to as much

as 43.7 percent in 1932 and 44.5 in 1947.

Twenty-three measured peak discharges were used with the 1-day precipitation (averaged for 2 gages in the watershed) and the antecedent 21-day precipitation as meteorological controls. Regression analysis gave a value for the cover density function of -0.914 which agrees closely with the -0.852 value from equation (a), table 3. Since the -0.852 value was obtained from much more comprehensive data it was used in evaluating the cover effect on discharges throughout this report. The cover function was used both for adjusting discharges to comparable cover conditions so they could be used in frequency determinations and for estimation of effects of flood-control measures which influence cover density or could be shown to be relatable to cover density.

"Present" Peak Discharge Frequencies.--Using the extended discharge record of Big Santa Anita as a base, the discharge frequencies of other watersheds for "present" watershed conditions were obtained.

This "present" watershed condition is defined as the average cover density that would exist over a period of time under the current level of fire protection and current grazing and agricultural land practices. Thus, "present" cover density for a watershed may be different from the actual 1950 cover density insofar as the fire occurrence during the preceding several years has not been "average."

Discharge frequencies for this "present" watershed condition were obtained as follows: each of the observed peak discharges of a new watershed with its associated cover condition was converted to its expected value under "present" watershed cover conditions by use of the cover function, equation (a), table 3, and by the ratios of the cover density actually on the watershed at the time the discharge was measured to the cover density expected (on the average) under "present" level of fire protection.

For example, the measured peak discharge of the Santa Paula Creek for the January 1, 1934, storm was 10,000 c.f.s. and the cover density was 29.0 percent. The expected cover density for the watershed under "present" conditions is 43.33 percent. The discharge converted to "present" cover condition is $10{,}000 \times (43.33/29.0)^{-.852} = 7{,}100$ c.f.s. The 7,100 c.f.s. was used instead of the measured 10,000. In the same manner all discharges were converted to the constant watershed cover condition before being used.

After correcting the discharges of a watershed to a constant comparable condition, the relationship between peak discharges of that watershed and the peak discharges of Big Santa Anita for the same storm was obtained. Figure 5 shows such a trend between Big Santa Anita and Santa Paula Creek. Using the trend line of figure 5 and the long-term record of discharges developed for Big Santa Anita, the peak discharge record for Santa Paula Creek was extended and filled in to make a 69-year record, then the frequency of peak discharges obtained, figure 6. In the same

way frequencies were obtained for all subwatersheds of the Santa Clara, Ventura, and Calleguas basins. These are given in table 5, columns 2 to 5, in such a way that the frequenty curves may be reproduced.

Program Effects on Peak Discharges.--The evaluation of the probable effects of various measures proposed for flood damage reduction is the end product of the hydrologic analyses. The frequencies of peak discharges provide a hydrologic base for estimating expected damages under "present" conditions. After the effects of proposed flood-control measures on peak discharges are determined, the effects on flood damages may be estimated. There are three general categories of measures requiring evaluation: fire control, range improvements, and cropland improvements.

Effect of Fire Control.--The intensified fire-control measures have as their objective the maintenance of an optimum wild-land cover density with the goal expressed as a reduction in the average annual acreage of area burned. The physical effect of reduction in burn percent is a smaller area of low density young cover, and therefore greater average cover density on the watershed. The relation of cover density to cover age for various geological-soil groups and various species was developed by J. S. Horton, and is summarized in table 6 so that the growth curves may be reproduced. The average cover density on a watershed is then the area weighted average of the cover densities read from the appropriate growth curves for the particular age of the cover. The average annual burn is converted to its equivalent cover density by assuming that age distribution is the same as if the annual burn occurred each year; thus, if the average annual burn were 1 percent there would be 1 percent of the area in each age class from zero to 99 years old. The average cover density would be read from the appropriate growth curves or in practice an average recovery curve was drawn for a watershed and that curve used to obtain average cover density for a particular burn percent. The effect of a change in burn percent resulting from intensified fire control was converted to change in average cover density on the watershed.

The effect of the change in cover on peak discharges was obtained by substitution in equation (a), table 3. For example, the present expected annual burn in the Santa Paula Creek watershed was 2.00 percent and the fire-control measures were designed to reduce this to 0.2 percent. The average cover densities under the two conditions would be 43.33 and 50.30 percent, respectively. The equation showed peak discharges varied as the -0.852 power of the cover densities; so $(50.30/43.33)^{-.852}$ gives 0.881 as the factor by which peak discharges would be reduced by the proposed fire-control measures, that is, an equivalent of 11.8 percent reduction in "present" discharges.

Effect of Range and Cropland Improvements on Peak Discharges.--For the estimation of the effect of improved grazing and cropland management on discharges it was necessary to make indirect estimation by using infiltration indices.

The influence of grazing intensity on infiltration capacity under controlled experimental conditions is indicated by the following results at the San Joaquin Experimental Range:

Number of plots	Experimental treatment	Number of tests	Infiltration capacity, soil at field capacity (Inches per hour)	Significance
3	Ungrazed 5 years	9	8.0	
3	Ungrazed 3 years, moderately grazed 2 years	9	5.8	Significant
3	Ungrazed 3 years, heavily grazed 2 years	9	3.4	Highly significant

These infiltration determinations are indicative of the changes in the hydrologic characteristics of the soil under grazing conditions. Similar indices were developed for grazing conditions in the Santa Clara and Ventura area and their hydrologic effects evaluated.

Three intensities of grazing were recognized--heavy, moderate, and light. Infiltration measurements had been made in the adjacent Santa Maria watersheds on the three types using the type FA infiltrometer. Seventeen determinations were taken on heavily grazed areas, 22 on moderately grazed, 12 on the lightly grazed, and 42 on various degrees and types of agricultural lands. Similar determinations were made in chaparral cover types of various ages and cover densities. For the latter it will be recalled that direct determination of the effects of cover density changes on discharges had been made by regression analyses discussed previously. Conversion of the grazing intensity classes to their hydrologic equivalents in terms of cover densities was made by using the infiltration measurements as indices. The following steps were taken:

1) The infiltration capacities as determined by the infiltrometer were multiplied by a factor of 0.3. 1/ These are called the adjusted infiltration

1/ From "A Method of Hydrologic Analysis in Watershed Management," P. B. Rowe. Trans. Amer. Geophys. Union, Pt. II, 1944, pp. 632-49. It was found, after allowance for soil and channel storage had been made, that if the infiltration measurements were multiplied by a factor of 0.3, approximate reproduction of the stream flow hydrograph resulted. It should be noted that the same relative effects of grazing intensities and agricultural uses are obtained by using either the unadjusted or the adjusted infiltration indices, but the adjusted values give positive values of rainfall excess for storms which are known to produce surface runoff and yield equivalent cover densities which are close to the observed for the various uses, so the adjusted indices will be used.

indices. Unadjusted and adjusted infiltration for various land-use categories involved in measures for flood and sediment reduction are given below:

Cover type	Degree of use or cover age	FA infiltration capacities 70-90 minutes after start of application (In./hr.)	Adjusted infiltration index (In./hr.)
Grassland	Heavy	0.62	.19
	Moderate	1.88	.57
	Light	3.12	.94
Cultivated			
Clean tilled		0.30	0.09
Treated		1.14	0.34
Chaparral	0-3 years old	1.21	.36
	4-7 years old	3.16	.95
	8-15 years old	4.85	1.46
	16+ years old	6.52	1.96

2) Maximum rainfall rates for several frequencies of storms were then estimated. These were developed from Corps of Engineers design storm data and are given below:

Cover type	Maximum hourly rainfall rates for storms of various recurrence intervals		
	100-year (In./hr.)	50-year (In./hr.)	25-year (In./hr.)
Grassland	1.37	1.18	1.00
Cultivated	1.37	1.18	1.00
Chaparral	1.75	1.48	1.25

3) Rainfall excesses over infiltration, for the cover conditions and ages for the various sizes of storms, were obtained by subtracting the adjusted infiltration indices from the rainfall rates:

Cover type	Cover density (Percent)	Rainfall excess for storms of recurrence intervals 100-year (Inches)	50-year (Inches)	25-year (Inches)
Grassland				
Heavy use	1/6	1.18	0.99	0.81
Moderate use	1/13	0.80	0.61	0.43
Light use	1/42	0.43	0.24	0.06
Cultivated				
Clean tilled	1/4.7	1.28	1.09	0.91
Treated	1/9.2	1.03	0.84	0.66
Chaparral				
0-3 years old	4	1.39	1.12	0.89
4-7 years old	14	0.80	0.53	0.30
8-15 years old	54	0.29	0.02	0
16+ years old	65	0	0	0

1/ Estimated equivalent effective cover density based on comparative rainfall excesses with chaparral cover.

If we assume that rainfall excess is an index of relative runoff-producing potential, we can obtain an estimate in terms of cover density of the effectiveness of light, moderate, and heavy grazing and of treatment of agricultural land on runoff. For example, the rainfall excess under moderate grazing for the 100-, 50-, and 25-year storms, were 0.80, 0.61, and 0.43 inch, respectively; reference to the standard, the chaparral, shows that these excesses are obtained under about a 13 percent cover density. Hence, moderate grazing use was assigned 13 percent as equivalent cover density effectiveness.

The equivalent cover densities for light, moderate, and heavy grazing and for 2 agricultural land classes were obtained by similar comparisons of rainfall excesses and are listed in column 1 of the above table.

Expressing this effectiveness in terms of equivalent chaparral cover density will permit estimation of effects on peak discharges of changing a given area from one degree of use to another. The estimate of the effect on discharges is obtained by substituting the equivalent cover change in equation (a), table 3.

The resulting changes in peak discharges for the program outlined in Appendix 4 are shown in table 5. The factors given were obtained by substituting equivalent cover densities in the equation as illustrated on page 8 of this appendix. The flood flows expected under "present" watershed conditions when multiplied by these factors give flood frequencies expected in the future without and with the program.

RELATION OF SEDIMENT PRODUCTION TO SEDIMENT-PRODUCING EVENTS, GEOLOGY, AND WATERSHED CONDITIONS

An important source of the damages produced in watersheds is the sediment produced by the floods. Deposition in reservoirs restricts their usefulness; deposition in stream channels restricts their capacity to carry flood flows. Determination of the expected sediment production rates from subwatersheds of the Santa Clara, Ventura, and Calleguas Creek basins are needed for flood-control evaluation. The average annual sedimentation may be said to depend on 1) the frequency of events causing sediment movement--peak discharges may be used as the defined event--and 2) on the relation of the amount of sediment produced to the size of these events for various watershed characteristics and conditions. Frequencies of discharges expected from the watersheds have been developed previously, table 5.

Twenty-three yearly catches of sediment in reservoirs were used to establish the basic relationship of sedimentation to discharges and watershed conditions. Multiple regression analysis was made of these 23 yearly catches of sediment with the associated maximum yearly discharge used as an expression of the sediment-producing potential of the year, the area of the main channel of the watershed as an expression of the amount of readily available material, and the cover density as the expression of watershed conditions.

The result of the analysis was equation (b), table 3. The peak discharge variable was significant at the 1 percent level. The other two variables, area of channel and cover density, have been included because each is significant at the 5 percent level when tested separately in an equation with peak discharges, so rather than using one or the other, both were included to give the most reliable measure of their individual effects and the best estimation of sedimentation.

Since this equation was developed from data where watershed geology is dominantly igneous and metamorphic rocks, tests of both the discharge and cover functions and adjustments of the constant in the equation for geologic variations were made.

Test of Relation of Sediment Production to Discharges.--The test of the discharge function of equation (b), table 3, for possible differences associated with geology which is dominantly marine sediments was made from data of the nearby Gibraltar reservoir watershed. Eight periodic measurements of sediment production in the Gibraltar reservoir provided the basis for the test, table 7. Regression analysis of the sediment catches against the discharge function being tested ($q^{.866}$) from equation (b), table 3, and the average cover density during each period, table 7, gave equation (c), table 3. The factor 0.945 for the discharge function is considered to be close enough to 1.00 to indicate that no modification of that function need be made for the Gibraltar watershed.

Thus it was shown that the function relating sediment production to

peak discharges found in other southern California watersheds also held in the Gibraltar watershed. Therefore, it was considered unnecessary to make any adjustments in the discharge function before use in Santa Clara and Ventura basins.

Test of Relation of Sediment Production to Watershed Cover.--As with the discharge function, the relationship of sediment production to cover density found in some other southern California watersheds (equation (b), table 3) was checked. The catches in 4 reservoirs, the Gibraltar, the Juncal, the Mono, and the Caliente, all in the adjacent Santa Ynez drainage, were used. Although peak discharges were available only for the Gibraltar, by using the precipitation effectiveness (1.619 log P'_1 + 0.410 log aP'_{21}) from equation (d), table 3, it was possible to use all 13 of the sediment catches, table 7. Regression analysis of these average annual sediment catches against the average precipitation effectiveness and the average cover density during the periods gave equation (e), table 3, as the result. The factor for precipitation effectiveness is seen to be 0.941 which is close to 1.00, and the factor for cover density was -1.980, which is practically identical with the -1.974 obtained in the more extensive southern California studies and given by equation (d), table 3.

Thus it was shown that not only the function relating sediment production to discharges but also the function relating sediment production to cover which was found in other southern California watersheds held also for watersheds where marine sediments dominated.

Although the general functions relating sediment production to flood peaks and cover density, obtained from more numerous data in southern California, were found to be usable in Santa Clara and Ventura watersheds, marked differences in the constant in the equation, that is, in the sediment production per unit discharge from watershed to watershed, were found. These differences were found to be related to the geologic-soil characteristics of the watersheds.

Relation of Sediment Production to Soil-Geologic Types.--The actual measured sedimentation in the Gibraltar watershed was used as a base for 1) adjusting the constant in equation (b), table 3, for soil-geologic differences and 2) as the reference from which estimates of expected sediment production from Santa Clara and Ventura watersheds could be made by application of discharges and cover and adjustment for differences in soil erodibility.

First an equation for sedimentation in Gibraltar was obtained by adjusting equation (b), table 3, on the basis of the ratio of the computed sedimentation for the 27-year period to the actual sedimentation. This gave an adjustment factor of 0.445 which incorporated in equation (b), gives equation (f), table 3.

Sedimentation expected from subwatersheds of the Santa Clara and Ventura watersheds varied from those of the Gibraltar due to variation in the

frequency of peak discharges, in the cover density, in the ratio of annual to peak discharge, and in the inherent differences in the erodibility of the soils of the areas. Equation (f), table 3, gives the relation of sedimentation to each of the factors, except the last two: 1) the ratio of annual to peak flow and 2) the erodibility. To obtain indices of "erodibility" it was found desirable to take soil samples from the major soil-geologic types, determine some of their physical characteristics in the laboratory, and test how these physical characteristics were related to measured sediment production from watersheds.

Several soil scientists have proposed physical characteristics of soils which are related to soil erodibility. The work of Middleton was a notable early attempt. He determined the physical characteristics of some soils and found that those soils with high values of these characteristics (dispersion ratios greater than 15, erosion ratios greater than 10) were generally classed as erodible; whereas those with low values were generally the nonerodible. These results suggested that indices of soil erodibility might be obtained from relatively simple soil measurements. Therefore, soil samples were collected from the major soil-geologic types in the Santa Maria and Santa Ynez drainages which are adjacent to the Santa Clara and Ventura and have many of the same geologic types.

Soil Sampling.--Soil samples of the 0- to 6-inch depth of soil were taken so as to have one or more samples from each major soil-geologic type in the watershed. The samples were all collected on slopes of about 35 percent and under cover conditions which were judged to be average for the vegetation type. Each sample was subjected to laboratory physical analyses, including mechanical analysis from rock and gravel to clay down to 0.15 microns, colloids by absorption, suspended silt plus clay after shaking for 0, 2, 20, 180, and 1,440 minutes, and the moisture equivalent. From the results of these determinations, several erosion ratios were calculated and tested.

Relation of Physical Soil Characteristics to Sediment Production.--Before the soil physical characteristics could be used to estimate sediment production from watersheds, tests were made to determine their relation to sediment production and how they were quantitatively related.

Some measured sediment productions from watersheds were available for the watersheds in which the soil samples were taken. These were of two kinds: stream suspended load measurements and sediment deposition in reservoirs. The average sediment content of the streamflow for 14 watersheds varying in area from 10.6 to 1,763 square miles had been determined, table 8. In addition, the sediment deposition in 4 reservoirs with watershed areas of from 16 to 219 square miles had been measured. The last included 13 measurements of sediment deposition and are given in table 7. Thus, 14 watersheds with their sediment production measured in terms of suspended sediment and four watersheds with their sediment production measured in terms of sediment deposited in their reservoirs furnished the bases for testing the relation of soil physical characteristics to sediment production.

Many physical soil characteristics were tried as parameters. Combinations of suspended silt plus clay, ultimate silt plus clay, micro clay, colloids, gravel, and moisture equivalent were studied. The ratios which were proposed by Middleton to express erodibility proved to be about as good as any new ones tested. The basic physical determinations and the most promising erosion ratios for the various major soil-geologic types are given in table 9. The areas of the various geologic types in the watersheds used in the analyses (and in the final application of the results) are given in table 10 together with the erosion ratios for the watersheds.

For the areas above sediment measurement points, the average values of the "erosion ratios" were determined by weighting the mean ratio for the soil-geologic type by the areal extents of the geologic types in the watershed.

Suspended Sediment.--The relation of the amount of suspended sediment to the various erosion ratios of the soils in the watershed was determined by regression analyses of the data of table 8. Table 3 gives equations (h) and (j) which are the least-square fits of the data, and also shows the correlation coefficient for these two analyses. In both, the cover density, C, and the suspension to colloid ratio, S/C, were highly significant. The relation of calculated to actual sediment is shown in figure 7 for the erodibility ratio, suspended silt plus clay/colloids, S/C. Any of the three erosion ratios listed would give a good enough index of relative erodibility, but the S/C ratio was selected because it seemed theoretically most sound and had the least standard error.

Sediment Deposition.--The relation of the amount of sediment deposition in reservoirs to the erosion ratios was determined by regression analysis of the 13 catches and the erosion ratios given in table 7. Equation (i), table 3, gives the equation relating sediment deposition to the ratio suspended silt plus clay/colloids when the meteorological and cover effects had been taken into account.

It will be noticed that the function for the S/C erodibility variable was nearly identical in the suspended sediment and the sediment deposition equations: 0.0146 and 0.0183. This, in a way, constitutes a check of the results. The S/C function for deposition equation (i), table 3, has been used to calculate the erodibility of the soils of the various watersheds. The relative erodibilities of all subwatersheds of the Santa Clara--Ventura and Calleguas Creek drainages are given in column 3 of table 11 (with Gibraltar taken as 100 percent.)

Effect on Sedimentation of Ratio of Annual to Peak Flow.--The peak yearly flow as an index of the sediment-producing potential of the year's discharges was a highly useful simplification. This simplification worked well as shown by the tests employed; however, some improvement was possible by including the annual flow as an additional parameter of sediment-producing potential of a year's discharges.

For 9 yearly catches of sediment and associated measurements of discharge into the San Dimas and San Gabriel No. 1 reservoirs, the ratio of the actual sedimentation to the sedimentation calculated from equation (b), table 3, was plotted against the ratio of the total annual inflow, in acre-feet, to the discharge function $q^{.866}$ (equation (b)). The trend line indicated some increase in sedimentation with relatively large annual inflows compared to peak inflow. The relation was such that the ratio of actual to calculated sedimentation varied as the 0.327 power of the ratio of annual inflow to the peak inflow function. Using this relationship, "Relative Discharge Factors," RD, ranging from 74 for Santa Clara River at Saugus to 112 for Matilija Creek were obtained for these watersheds when Gibraltar was taken as 100. These relative discharge factors for sedimentation are given in column 4 of table 11 for all subwatersheds.

Incorporating both the relative discharge factor and the relative erodibility factor into equation (f), table 3, gave equation (g), which applies to each of the Santa Clara and Ventura subdrainages.

Average Annual Sedimentation.--The peak discharge frequencies developed give expected number and sizes of future floods (table 5) and equation (g), table 3, gives the amount of annual sedimentation for any size flood--for some particular watershed cover condition. Average annual sedimentation is merely the sum of the annual erosions obtained by substituting the discharges from the frequency curve in the equation with proper values of cover density and the other variables. Sedimentation estimates for "present" watershed conditions for subdrainages of the Santa Clara, Ventura, and Calleguas Creek are given in column 5, table 11.

These values were checked for two watersheds by comparing the sedimentation calculated in this way with that of average suspended sediment times the average annual total streamflow. The data pertinent to the test are given below:

Watershed	Area	Mean annual flow	Cover density 1/	Average suspended sediment 2/	Suspended sediment 3/	Calculated total sediment production 4/	Ratio calculated total sediment to suspended sediment
	(Sq.mi.)	(AF/yr.)	(Percent)	(Tons/AF)	(C.y./sq. mi./yr.)	(C.y./sq. mi./yr.)	
Sespe	254	91,000	51.3	3.98	1,320	1,750	1.33
Piru	432	51,100	41.8	34.3	3,760	4,060	1.08

1/ Average cover density on watershed during time of sediment measurement.

2/ From data of Santa Clara Water Conservation District Reports, 1932-35.

3/ Average annual flow times average suspended sediment allowing 80 pounds per cubic foot for weight of sediment.

4/ By equation (g), table 3, and the constants in table 11.

The test shows that the total sedimentation is somewhat greater than the suspended sediment as would be expected. The ratios 1.33 and 1.08 of calculated total sediment production to the measured suspended load for Sespe and Piru watersheds constitute a crude check on the calculated sedimentation rates.

Effect of Program on Expected Sedimentation.--The effects of program on expected sedimentation depend on the effects of the several measures on discharges and then their additional effect on the amount of sediment per unit discharge. In the section "Program Effects on Discharge" the effects of flood-control measures have been shown to be expressible in terms of their effects on average cover density in the case of fire control and in terms of equivalent cover density in the case of the range and cropland improvements. The gross effect of changing cover density on sedimentation is given by the cover function in equation (d), table 3. The change in sedimentation with change in cover density is seen to vary as the -1.974 power of the cover densities. This change is verified rather well by independent studies of the cover effects obtained from other data (equations (e), (i), and (j), table 3). Using the changes in cover associated with the fire, range, and agricultural land measures the estimated sediment production is obtained. For example, the Matilija watershed has an expected average annual sedimentation production rate of 2,515 cubic yards per square mile under "present" fire protection level with an associated average cover density of 50.7 percent. Under intensified fire protection the average cover age would increase and the cover density would be 58.8 percent. Reduction of sedimentation by fire control is then $2,515 [1-(58.8/50.7)^{-1.974}]$ or an average of 639 cubic yards per square mile per year for the whole 55 square-milewatershed which is

a 25 percent reduction. The future watershed conditions with and without the program outlined in Appendix 4 were converted to their equivalent change in cover density (table 12, Appendix 4) by using the tabulation on page 11, this appendix. In the same manner as illustrated for the fire protection plan the changes that the range and cropland measures will make in "present" sediment rates were calculated, and the total effect of the recommended program is given in table 11.

An illustration of how fire increases sediment production is presented in the annual reports of the Santa Clara Water Conservation District, 1931-32 to 1934-35. The data include some for the Sespe watershed. The District took stream sediment samples the year before and for several years following the 1932 fire which burned 76 percent of the Sespe watershed. The difference in sediment production is strikingly shown when sediment concentration in the water is plotted against streamflow, figure 8. The runoff water for the first 2 years after the fire had an average of 6 times as much sediment as the year before the fire. The streamflow from the first storm after the fire had very high concentrations of ash and debris--2,400 ppm of soluble matter and 400,000 ppm of suspended sediment.

Channel Sedimentation.--What happens to the sediment produced from these watersheds? Some of it goes into the sea. Some of it is deposited, before it reaches the ocean, in reservoirs where they have been built or in the main stream channel.

In an effort to obtain an indication of the rate of sedimentation of the Santa Clara River channel a study was made of detailed topographic maps prepared in 1928 and 1948. The effect of sedimentation on overflow area for various size floods was the primary aim of the investigation. The reach of channel covered by the study extended from Saticoy Bridge to the Los Angeles County line, a distance of about 28 miles. Cross sections between Santa Paula and West Piru obtained immediately after the 1938 flood by the Soil Conservation Service, were compared with data from the 1928 and 1948 surveys.

The study indicates that sediment movement within the overflow area of large floods is extremely erratic. Sedimentation and scour occur throughout this reach of channel. The average rate of sedimentation from 1928 to 1948 is about 2 acre feet per mile of channel per year. For the 5.5 miles of channel for which overflow areas were calculated the acreage of inundation for 50,000 and 100,000 cfs flows would have been slightly less in the 1948 channel than the same flows in the 1928 channel. The rate of sedimentation, during the 20 year period, for this same reach of channel was about 2.5 times the average rate for the entire reach studied.

The total net amount of sediment deposited for the 1928 to 1948 period amounts to about 1,784,000 cubic yards in the 28 mile reach of channel studied. The tributary drainage area above the lower end of this reach is about 1,500 square miles and the drainage area above the upper end of the reach is about 940 square miles. The 1938 cross sections indicate that sedimentation occurred from 1928 to 1938 and scour occurred from 1938 to 1948. It is evident from this study that channel cross sections

taken more or less at random several thousand feet apart will not give an accurate quantitative picture of the changes resulting from floods in this channel. In the 5.5 mile reach of channel for which overflow areas were estimated, less acreage would be inundated by both 50,000 and 100,000 second feet floods under 1948 channel conditions than under 1928 channel conditions. Although a small amount of sedimentation has occurred in this reach the channel capacity has been increased as a result of scour, thus deepening and steepening the channel, generally near the south bank. As an illustration of this, the data for the cross sections at Stations 40+00 and 240+00 are given below.

Discharge data for Selected cross sections

Station	Below Elevation	1928 channel conditions: Area of cross section	Channel slope	Hydraulic radius	Capacity	1948 channel conditions: Area of cross section	Channel slope	Hydraulic radius	Capacity
	Feet	Sq.ft.	Feet/foot	Feet	cfs	Sq.ft.	Feet/foot	Feet	cfs
40+00	150	25,740	.00175	6.48	139,000	24,940	.00264	6.31	166,000
	148	17,880	.00175	4.55	76,400	17,300	.00264	4.42	90,000
	146	10,360	.00175	3.74	39,000	10,200	.00264	4.42	53,000
240+00	214	17,840	.00206	6.56	105,600	17,480	.00276	6.25	115,500
	212	12,740	.00206	5.27	66,600	12,220	.00276	4.90	68,600

It will be noted that the decrease in slope between 1928 and 1948 is sufficient to create a greater flow capacity although the area of the flow section is greater in 1928 than in 1948 except in the section below elevation 146 at Station 40+00. In this section greater average depth of flow combined with the increased slope give a capacity about 1/3 greater in 1948 than it was in 1928 although the area of flow is 160 square feet less.

This method of computing overflow areas is applicable only when cross sections of the channel remain relatively constant during floods. No evidence exists that this is true in this channel. It is generally assumed that the bed load of a stream is greatest during the rising stages of a flood flow and smallest during low-water flow. Its amount is assumed to vary approximately as the 5/2 power of the stream velocity. Consequently, a flood flow coming from a section of high velocity into a section of low velocity will deposit bed load corresponding to the change in velocity. This deposition will fill the channel, thus decreasing its capacity during the rising stages of the flood. On the other hand, a flood flow coming from a section of low velocity into a section of high velocity will take on bed load and scour the channel, thereby increasing the capacity. The average conditions or capacity of a channel may mean very little in terms of its flood damaging potential. Flood damage can only occur where there is damageable property. When a condition exists or is developed during a flood that will cause overflow at the opportune spot in a channel at the correct instant great damage will result. This same condition developing at some other location in the channel will result in little or no damage.

In order to predict the amount of sediment and its effect on overflow areas, and thus damages, in the Santa Clara Valley, a great amount of information is needed on the changes of the channel during and between floods. A large number of properly established cross sections upon which accurate repeat measurements could be made over a long period of time is a necessary base from which to start. Accurate mapping of overflow areas of all floods as they occur and the damages resulting would also be necessary. Records of hydrologic occurances and vegetative changes of the watershed during the same period would be required, before a reliable estimate of probable future damage resulting from sedimentation can be made. Present knowledge is such that it is impossible to make a dependable evaluation of future effect of sedimentation in the Santa Clara River channel.

Design Sedimentation.--For purposes of designing reservoirs and evaluating their effectiveness and economic feasibility it is necessary to know the storage capacity which must be allowed for sediment over a period of time. The average annual sediment production has been determined for the Santa Clara, Ventura, and Calleguas streams by use of the equations developed and expected flood frequencies under certain assigned values of watershed cover densities.

In designing spreading grounds, channels, and debris reservoirs it is necessary to know the storage capacity which must be allowed for sediment for a single large storm, assuming some coincident poor watershed condition. An approximation of this allowable storage capacity may be obtained from the results of this study.

The storm which gives the flood of 100-year recurrence interval may be arbitrarily chosen. The area of brush cover may serve as an expression of fire hazard and a possible poor watershed condition might well be such as would result if an area equal to one-quarter of the brush area burned, and the storm occurred the first year after such a burn. By using the 200-year intercept of the discharge frequency curve (that for Santa Paula Creek shown in figure 6) or by extending values from the discharges given in table 5 as the mean size of this flood and using equations (a) and (g) of table 3 and the expected cover density and erodibility, we obtain the estimates of sedimentation listed in table 11, which have been termed "design sedimentation."

CONCLUSION

The studies made to develop a hydrologic base for evaluation of the flood-control program indicated the following:

1) The observed discharges in this area, where discharge records are short and major fires cause wide variation in forest cover, are not a satisfactory base for determining frequency. Adjustment of the observed discharges to a uniform forest cover condition and extension of the record on the basis of the long-term precipitation record provide such a base.

2) Sedimentation in an individual reservoir likewise is not often a good index of the long-time average to be expected. If the record of sedimentation is short, the floods during this period may not be representative. Even if the record of sedimentation is fairly long, the fire history may not be representative or the coincidence of fires and storms may be exceptional. Thus the actual sedimentation of a reservoir in the 219-square-mile Gibraltar watershed during a 27-year period is 1.3 acre-feet per square mile per year, whereas the expected amount under the present fire protection level, based on frequency of expected discharges, is only 0.9 acre-feet per square mile per year.

Sediment productions were highly variable from watershed to watershed depending on the geology of the area. Average suspended sediment of the runoff water was 2,370 ppm and 25,200 ppm for the 2 watersheds for which data were available. Both suspended sediment and sediment deposition were related to some physical characteristics of the various soil-geologic types. These relations provided a basis for improving the estimates of expected average annual sediment production.

Basing estimates of average sedimentation on the long-time extended discharge record and adjusting for erodibility and expected average cover conditions by use of the equations which were developed provided estimates which made allowance for widely varying erodibility and were independent of chance conditions of fire history.

3) Past discharges and sediment production in this basin have been moderately high. The studies indicated that improved fire protection, grazing practices, and cropland treatment can bring about sizable reductions in peak discharges and sediment production. For whole watersheds, reductions in future peak discharges ranged from 17 to 28 percent and reductions in sediment production from 37 to 68 percent.

It should be pointed out that the cover effects here measured, both for sedimentation and peak discharges, apply only to the present general level of watershed conditions. If during some future interval of time, the watershed receives improved treatment and protection for a long period, then soil building may occur and the maximum cover density may have an effect even greater than found here. If, on the other hand, further misuse continues, the vegetation which occupies the area may be expected to become less and less dense. Under such conditions of decreased cover effectiveness, cover changes will be necessarily smaller, and a sustained higher level of peak discharges and sedimentation may be expected to result.

4) Sediment production from the tributaries of the Santa Clara watershed was found to be aggrading the main channel and restricting its capacity to carry future floods. Remeasurements in 1938 of original cross sections made in 1929 indicated deposition of 1,480 acre-feet per year between Saugus and Saticoy, or 42.9 percent of the total estimated sediment production. An independent check, using sediment sampling from the tributaries and at the mouth of the river gave a comparable figure of 46.3 percent deposition. The proposed program will not only reduce damages by reduction in flood peaks, but will reduce sediment production which will tend to maintain channel capacity in the main rivers.

5) As to the adequacy of the methods employed, the study complies fairly well with the six criteria upon which a study in applied hydrology may be evaluated: in determining the basic relations (1) the data are representative in time; this was considered to be fairly well met because the data used covered 30 years of discharges and 69 years of meteorological records; (2) the data used are representative in space, relations used were based on rather extensive studies in nearby areas of southern California and tested for their applicability to this area; (3) the effects measured are representative of actual effects, in this case they were the actual effects of meteorological and watershed variables on discharges and sediment production from whole watersheds in the case of fire effects and the use of infiltration indices in the cases of the grazing and cropland treatment effects; (4) the effects measured are related to the desired end products, the damages produced by floods; (5) a suitable measuring device was employed, multiple regression analysis; and (6) in the application of the results, tests were made for the individual cases whenever possible. Despite attempts at obtaining adequate statistical bases for the findings and devising of checks on the findings, the possibility of error cannot be overlooked. In order that the assumptions, reasonings, and evaluations may be checked, full data have been given insofar as practicable.

Table 1.--Maximum daily precipitation of storms and associated 21-day antecedent precipitation for Big Santa Anita watershed for 69-year period, Oct. 29, 1877, to April 6, 1946

(Numbers in parentheses are for period Oct. 1, 1916, to April 30, 1946)

Maximum daily precipitation in inches	Twenty-one-day antecedent precipitation--inches					
	< 2.00	2.00-3.99	4.00-7.99	8.00-15.99	16.00-31.99	>31.99
0.02-0.99	765 (325)	147 (68)	120 (50)	74 (24)	32 (12)	1 (1)
1.00-1.99	130 (51)	45 (26)	35 (17)	31 (13)	6 (2)	
2.00-2.99	38 (16)	21 (10)	25 (17)	14 (4)	8 (5)	
3.00-3.99	22 (8)	7 (3)	9 (5)	11 (3)	2 (1)	
4.00-4.99	7 (5)	9 (3)	9 (3)	5 (4)	3 (2)	1 (0)
5.00-5.99		3 (1)	3 (2)	3 (2)	2 (0)	
6.00-6.99	2 (1)	2 (0)	3 (1)	1 (1)		
7.00-7.99	1 (0)			1 (1)		
8.00-8.99	3 (1)	1 (0)				
9.00-9.99				1 (1)		
10.00-10.99	3 (0)			1 (0)		
11.00-11.99	1 (1)				1 (1)	
12.00-12.99						
13.00-13.99			1 (0)			
14.00-14.99						
15.00-15.99	1 (1)					
Totals	973	235	205	142	54	2

Grand total 1,611

Table 2.--Maximum discharge at gaging stations in Santa Clara and Ventura River watersheds

Watershed	Area	Period of record 1/	Maximum discharge during period 2/
	Sq.mi.		C.f.s.
Santa Clara River	355	Oct. 1929-Sept. 1947	24,000
Piru Creek	432	Oct. 1934-Sept. 1947	35,600
Hopper Creek	23	Oct. 1930-Sept. 1947	8,000
Sespe Creek	254	Oct. 1927-Sept. 1947	56,000
Santa Paula Creek	40	Oct. 1932-Sept. 1947	13,500
Ventura River	187	Oct. 1929-Sept. 1947	39,200
Matilija Creek	55	Oct. 1927-Sept. 1947	15,900
North Fork Matilija Creek	16	Oct. 1933-Sept. 1947	5,580
Coyote Creek	41	Oct. 1933-Sept. 1947	11,500
Calleguas Creek near Simi	78	1933-1942	1,700
Calleguas Creek near Moorpark	115	1933-1942	4,100

1/ Additional short period records are sometimes available.

2/ All maximum discharges occurred March 2, 1938.

Table 3.--Equations relating peak discharges and sediment production from watersheds to their causes 1/

No.	Equation	Number of data	Correlation coefficient	Standard error of estimate
(a) 2/	$\log Q = 1.293 + 1.082 \log A + 1.870 \log P_1 + 0.474 \log aP_{21} - 0.852 \log C$	127	.942	±.301
(b) 2/	$\log e_D = 1.041 + 0.866 \log q + 0.370 \log A_{ch} - 1.236 \log C$	23	.953	±.183
(c)	$\log e_D = 4.774 + 0.945 \log q_m{}^{.866} - 3.717 \log C$	8	.871	±.252
(d) 2/	$\log e_D = 2.161 + 0.071 \log A + 1.619 \log P'_1 + 0.410 \log aP'_{21} + 0.370 \log A_{ch} - 1.974 \log C$	--	--	--
(e)	$\log e_D = 2.092 + 0.941 \log PE_2 - 1.980 \log C$	13	.680	±.326
(f)	$\log e_D = 0.689 + 0.866 \log q - 1.236 \log C + 0.370 \log A_{ch}$	--	--	--
(g)	$\log e_D = \log RE/100 + \log RD/100 + 0.689 + 0.866 \log q - 1.236 \log C + 0.370 \log A_{ch}$	--	--	--
(h)	$\log E_s = 5.815 - 1.541 \log C + 0.0146\ S/C$	14	.911	±.245
(i)	$\log e_D = 1.678 + 1.120 \log PE_2 - 2.418 \log C + 0.0183\ S/C$	13	.732	±.319
(j)	$\log E_s = 3.561 - 2.093 \log C + 2.210 \log S/C$	14	.914	±.242

1/ For definitions and units of variables see table 4.

2/ From *Trans. Amer. Geophys. Union* 30 (4):567-534, 1949.

Table 4.--Definition, units, and ranges in variables

Symbol	Variable	Units	Range
Q	Momentary peak discharge from a watershed during the storm	C.f.s.	5-90,000
e_D	Sedimentation in reservoir	AF/sq.mi./yr.	0.3-36.0
E_s	Average suspended sediment content of streamflow	Ppm	3,900-192,300
P_1	Maximum 1-day precipitation during a storm	Inches	0.2-20.0
P'_1	Maximum 1-day precipitation for maximum storm of a year	Inches	
aP_{21}	Twenty-one-day precipitation antecedent to storm maximum 1-day	Inches	0.3-23.0
aP'_{21}	Twenty-one-day precipitation antecedent to maximum 1-day of maximum storm of a year	Inches	
A	Watershed area	Square miles	1.5-1,763
C	Average cover density on watershed	Percent	2.0-72.4
A_{ch}	Area of main channel of the watershed	Ac./sq. mile	1.7-9.7
q	Maximum yearly peak discharge	C.s.m.	10-550
$q_m^{.866}$	Mean of maximum yearly peak discharges to .866 power	--	8.8-59.9
PE_2	Average precipitation effectiveness, $1.619 \log P'_1 + 0.410 \log aP'_{21}$	Inches^2	0.82-1.48
RE	Relative erodibility, antilog $[1.678 + 0.0183\ S/C]$ Gibraltar taken as 100	--	41-3,746
RD	Relative discharge, 0.370 power of ratio of annual flow to peak flow of year to .866 power (Gibraltar taken as 100)		
S/C	Suspended silt + clay/colloids	100% / %	16.2-172.6
DR	Suspended silt + clay/ultimate silt + clay, after Middleton	% / %	14.1-49.6
ER	DR x moisture equivalent/colloids, after Middleton	% / %	
P_1/C	Joint variable of P_1 and C (nonsignificant)	--	
$P_1.aP_{21}$	Joint variable of P_1 and aP_{21} (nonsignificant)	--	
A/C	Joint variable of A and C (nonsignificant)	--	

Table 5.--Estimated peak discharges from watersheds for various watershed conditions

Watershed name	Area	Peak discharges for "present" watershed conditions for selected recurrence intervals, years 1/				Condition	Factors to convert discharges to future conditions 2/
		100	20	5	2		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Sq.mi.						
Santa Clara near Saugus	355	20,360	18,160	5,330	1,870	Without program	1.168
						With program	.851
Matilija Creek	55	16,090	9,190	3,910	1,920	Without program	1.073
						With program	.881
Calleguas Creek	115	9,290	5,530	1,570	254	Without program	1.043
						With program	.819
Coyote Creek near Ventura	41	18,260	9,240	3,880	1,680	Without program	1.079
						With program	.877
Piru Creek at Piru	432	35,620	18,480	7,240	3,230	Without program	1.111
						With program	.816
Sespe Creek near Fillmore	254	72,350	37,360	14,230	6,520	Without program	1.095
						With program	.829
Santa Paula Creek	40	14,590	7,930	2,880	1,290	Without program	1.082
						With program	.859
Ventura River	187	49,580	28,250	12,680	6,170	Without program	1.074
						With program	.851

1/ Maximum yearly discharge frequencies expected for long-term meteorological events and under existing fire-protection levels and existing grazing and agricultural use.

2/ These factors times the discharges listed give discharge frequencies expected within the next 20 years considering present trends in use and resultant watershed conditions with and without programs. Programs are given in detail in Appendix 4.

Table 6.--Vegetation density recovery rates following fire--by cover types for various geologic origins of soil parent materials

Cover type	Geology	Minimum cover density	Maximum cover density	Recovery rate (k) 1/
Oak chaparral	Metamorphic	0	90	0.156
	Igneous	0	80	0.139
	Sedimentary	0	65	0.152
Pure chamise and chamise sage	Metamorphic	0	60	0.110
	Sedimentary & igneous	0	50	0.058
	Anorthosite	0	40	0.037
Chamise-manzanita and chaparral	Metamorphic	0	80	0.123
	Igneous	0	75	0.116
	Sedimentary	0	65	0.112
High elevation chaparral	Metamorphic	0	80	0.138
	Sedimentary & igneous	0	70	0.143
Oak woodland (Quercus chrysolepis)	All	0	90	0.263
Oak woodland (Quercus agrifolia)	All	30	40	0.105
Desert chamise and chaparral	Metamorphic	0	65	0.100
	Igneous	0	60	0.094
	Sedimentary	0	30	0.080
Coastal sage	All	0	40	0.153
Desert sage	All	0	30	0.100
Semidesert	All	0	30	0.051
Pinon Juniper	All	10	25	0.074
Timberland chaparral	All	0	50	0.054
Semibarren	Metamorphic	0	20	0.093
	Sedimentary & igneous	0	20	0.053
Conifers	All	50	50	0

1/ Vegetation density recovery following fire, where if C_t is the cover density "t" years after a fire, C_{Min} is the minimum cover density after a fire, C_{Max} is the maximum change in cover density attained in about 40 years after a fire, t is the years after a fire, k is the constant representing the recovery rate, and e is the base of the natural logarithms; then C_t may be determined from the growth equation $C_t = C_{Min} + C_{Max}(1-e^{-kt})$.

Table 7.--Periodic sedimentation measurements of some reservoirs and associated discharge storm and watershed cover variables

Watershed name	Area	Period	Sedimentation	Mean $q^{.866}$	Average cover density 1/	Average log PE_2 2/	Average cover density 3/	Erosion ratios 4/ DR	ER	S/C
		Water year	AF/sq. mi./yr.							
Gibraltar	219	1921-31	5/0.45	8.8	41.6	0.94	45.2	25.2	21.0	52.8
		1932-34	3.42	27.8	36.4	1.48	36.8			
		1935-36	1.04	9.8	30.3	0.93	30.4			
		1937-38	4.31	59.9	34.0	1.26	33.9			
		1939-40	0.71	5.6	36.5	0.82	36.2			
		1941	3.84	26.3	38.2	1.27	38.2			
		1942-44	1.15	29.2	40.6	1.48	40.5			
		1945-47	0.29	12.5	43.1	1.18	43.5			
Juncal	16	1931-39	2.07			1.18	20.0	19.1	13.4	37.7
		1940-48	1.06			1.24	34.5			
Mono	119	1937	1.68			0.86	33.8	24.4	19.8	50.8
Caliente	40	1938	4.47			1.67	42.3	20.1	14.4	39.4
		1939-48	0.42			1.21	46.0			

1/ Weighted average--weighted on basis of 0.866 power of the maximum yearly discharge associated with each yearly cover density during the deposition period.

2/ Log $PE_2 = 1.619 \log P'_1 + 0.410 \log aP'_{21}$ from equation (d), table 3.

3/ Weighted average--weighted on basis of PE_2 associated with each yearly cover density during the deposition period.

4/ DR, ER, and S/C are respectively Middleton's dispersion and erosion ratios and 100 times the ratio of suspension percent to colloids percent. U.S.D.A. Tech. Bull. 178, 1930.

5/ Plus or minus error in original storage capacity measurement--original capacity of 13,746 acre-feet was used.

Table 8.--Average suspended sediment content of streamflow with associated cover density and mean erosion ratios of some south coastal watersheds, California

Watershed	Area	Average suspended sediment 1/	Cover density	Erosion ratios 2/ DR	ER	S/C
	Sq.miles	Ppm	Percent			
Cuyama	81	18,300	31.1	29.7	26.2	84.6
Cuyama	410	140,800	35.1	33.0	29.5	92.3
Cuyama	804	43,500	35.9	36.5	30.2	88.5
Cuyama	912	31,000	36.1	35.1	30.5	87.0
Sisquoc	442	11,100	48.7	32.5	28.8	68.9
Santa Maria	1,638	19,400	42.4	33.4	28.9	76.2
Santa Maria	1,763	30,200	42.3	33.6	29.0	78.6
Bradley	10.6	35,000	44.6	42.5	31.6	82.6
Ballinger	30	192,300	27.1	46.9	44.5	138.8
Tepusquet	13	7,600	44.8	22.6	16.2	42.5
Huasna	119	3,900	58.8	28.1	24.0	58.1
Sespe 3/	254	2,370	51.3	17.1	10.5	31.6
Sespe 4/	254	14,100	19.0	17.1	10.5	31.6
Alamo	89	5,300	53.9	32.4	29.5	69.8

1/ Except for the Sespe samples, all samples were taken in the water year 1940-41 by the U. S. Forest Service, Flood Control Survey Division.

2/ DR, ER, and S/C are respectively Middleton's dispersion ratio, erosion ratio, and 100 x the ratio of suspension percent to colloids. U.S.D.A. Tech. Bull. 178, 1930.

3/ Before 1932 fire.

4/ Average for first 2 years after 1932 fire which burned 76 percent of watershed.

Table 9.--Soil characteristics

Sample number	Geology 1/	Suspended si + cl 2/	Ultimate si + cl	M.E. 3/	Colloids 4/	Clay	Dispersion ratio 5/	Erosion ratio 6/	Suspension x 100 ÷ colloids
		Percent	Percent	Pct.	Percent	Pct.			
7	Mc	19.5	39.3	11.9	11.3	9.6	49.6	52.2	172.6
5	QP	16.1	37.9	14.5	19.5	13.0	42.5	31.6	82.6
1	Kc	22.4	61.3	26.5	27.5	13.8	36.6	35.2	81.4
8	Mm	14.6	54.5	19.7	24.4	21.6	26.8	21.6	59.8
11	Mm	16.1	74.1	26.8	36.1	38.4	22.7	16.8	44.6
10	Mm	16.5	77.3	27.3	38.3	36.9	21.4	15.3	43.1
4	Mm	12.0	53.5	20.1	31.3	18.0	22.4	14.4	38.3
9	Mm	16.1	70.9	35.2	50.0	26.7	22.7	16.0	32.2
2	Eu	15.2	94.1	23.4	39.0	35.6	16.1	9.6	39.0
3	Ks	5.1	36.2	16.3	31.4	13.7	14.1	7.3	16.2

1/ Geologic symbols in Geologic Map of California, Jenkins, 1938.

2/ Middleton's silt and clay, U.S.D.A. Tech. Bull. 178, 1930.

3/ Moisture equivalent.

4/ Colloids after method of W. O. Robinson.

5/ Middleton's dispersion ratio.

6/ Middleton's erosion ratio.

Table 10.--Geologic distribution in selected watersheds of the Santa Clara, Ventura, Calleguas Creek watersheds and above Gibraltar reservoir and resultant estimates of average erodibility

Watershed name	Area	Ko	Ks	MmMu	Mc	Eu	Ø	Qt-Qp	Mv-grd	Misc.	Weighted average suspension/colloids	Erodibility 2/	Relative erodibility 3/
	Geologic types--percent of watershed area 1/												
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	Sq.mi.												
Gibraltar	219	22.1	17.3	7.2		41.8				11.6	48.1	363	100
Santa Clara	355				13.6		4.6	7.2	41.9	32.7	81.8	1,496	412
Piru near Piru	432				14.7	10.4		5.8	42.1	27.0	81.0	1,446	399
Ventura	187			6.5		45.6	16.8	8.1		23.0	49.9	390	107
Calleguas	115	6.3		21.1		10.9	14.1		2.3	45.3	56.8	522	144
Matilija	55					96.4				3.6	40.0	257	71
Coyote Creek	41.1					40.0	51.1			8.9	42.8	289	80
Sespe Creek	254			10.2		51.6	27.2			11.0	43.3	295	81
Santa Paula Creek	40					63.6				36.4	49.5	383	106
Suspension/colloids		81.4	16.2	43.6	172.6	39.0	4/41.3	82.6	5/67.4	6/68.1			

1/ Symbols are standard geologic symbols and areas are from Geology Map of California, Jenkins, 1938.

2/ Antilog $[\bar{1}.6779 + 0.1831\ S/C]$. From equation (i), table 3.

3/ From column (12), Gibraltar taken as 100.

4/ Assumed to equal mean of Eu and Mm.

5/ From Gibraltar--igneous and metamorphic rocks were 2.25 as erodible as the mean of Gibraltar geologic types.

6/ Unweighted average of all types.

Table 11.--Average erodibility of soils of watersheds, estimated annual sediment production for various watershed conditions and "design" storm sedimentation

Subwatershed name	Area	Main channel area	Relative erodibility 1/	Relative discharge factors 2/	"Present" sedimentation rate 3/	Condition	Changes in sedimentation under future uses	Sediment reduction 4/	Design sedimentation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Sq. mi.	Ac./sq.mi.			Cu.yd./sq. mi./yr.		Cu.yd./sq. mi./yr.	Percent	Cu.yd./sq. mi./yr.
Gibraltar	219	2.2	100	100	1.500				
Santa Clara R. near Saugus	355	5.3	412	74	3,542	Without program	+1,544		52,100
						With program	-1,105	52.1	
Matilija Creek	55	7.0	71	112	2,515	Without program	+445		22,500
						With program	-639	36.6	
Calleguas Creek	115	1.0	144	100	927	Without program	+67		8,800
						With program	5/-613	68.4	
Coyote Creek near Ventura	41	2.0	80	86	1,950	Without program	+374		20,200
						With program	-513	38.2	
Sespe Creek near Fillmore	254	5.6	81	106	2,494	Without program	+589		26,300
						With program	-880	47.6	
Piru Creek near Piru	432	4.9	399	105	4,747	Without program	+1,320		38,900
						With program	-1,785	51.2	
Santa Paula Creek	40	2.3	106	109	2,710	Without program	+539		32,300
						With program	-813	41.6	

Continued

Table 11.--Average erodibility of soils of watersheds, estimated annual sediment production for various watershed conditions and "design" storm sedimentation - contd.

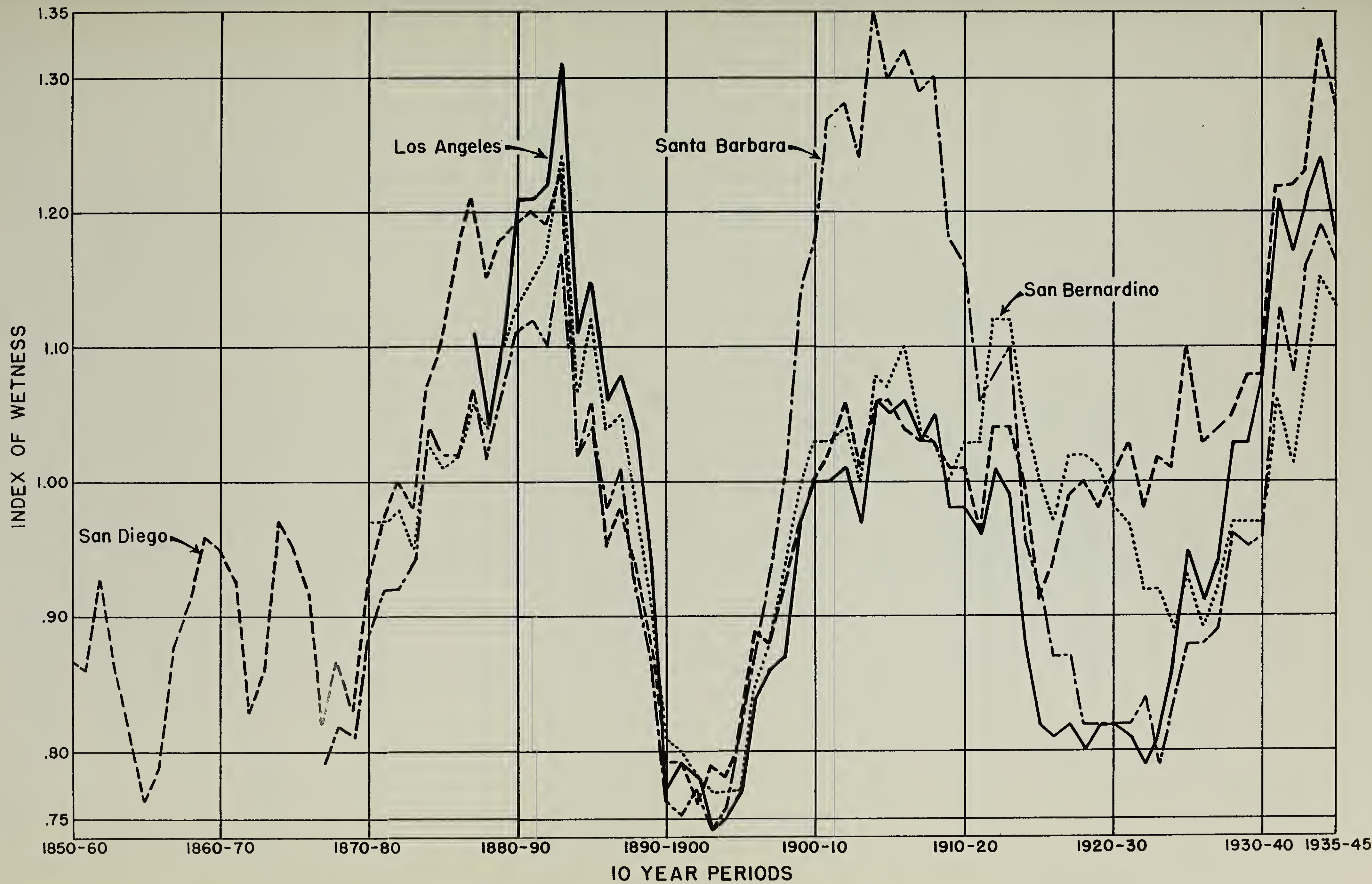
1/ Based on soil geologic types. See table 10.

2/ Study of nine yearly sedimentation measurements and associated annual peak inflow data from San Dimas and San Gabriel watersheds shows sediment production varied as 0.327 power or ratio of annual runoff in acre-feet per square mile to the maximum yearly runoff c.f.s. per square mile to 0.866 power. Taking Gibraltrar as 100, these "relative discharge factors" were obtained.

3/ Calculated from equation (g), table 3, using discharge frequencies of table 5 and the area of channel, relative erodibility, and relative discharge factors of columns 2, 3, and 4.

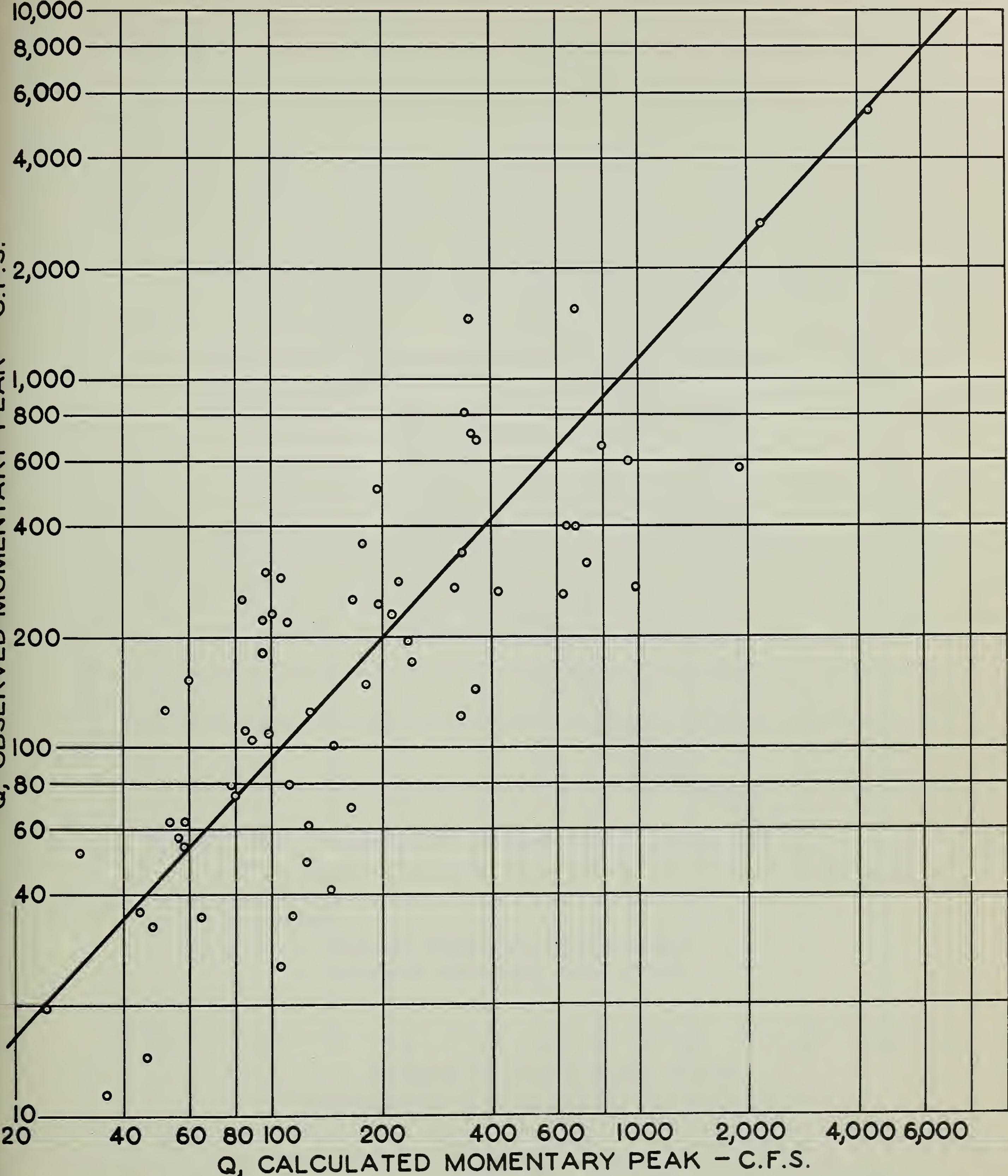
4/ Sediment reduction with program expressed as a percent of expected sedimentation without program.

5/ Sediment reduction due to agricultural land measures on this watershed was furnished by the Soil Conservation Service; all other agricultural land reductions were obtained by the methods outlined in the text.



PROGRESSIVE 10 YEAR MEAN PRECIPITATION AT SELECTED STATIONS

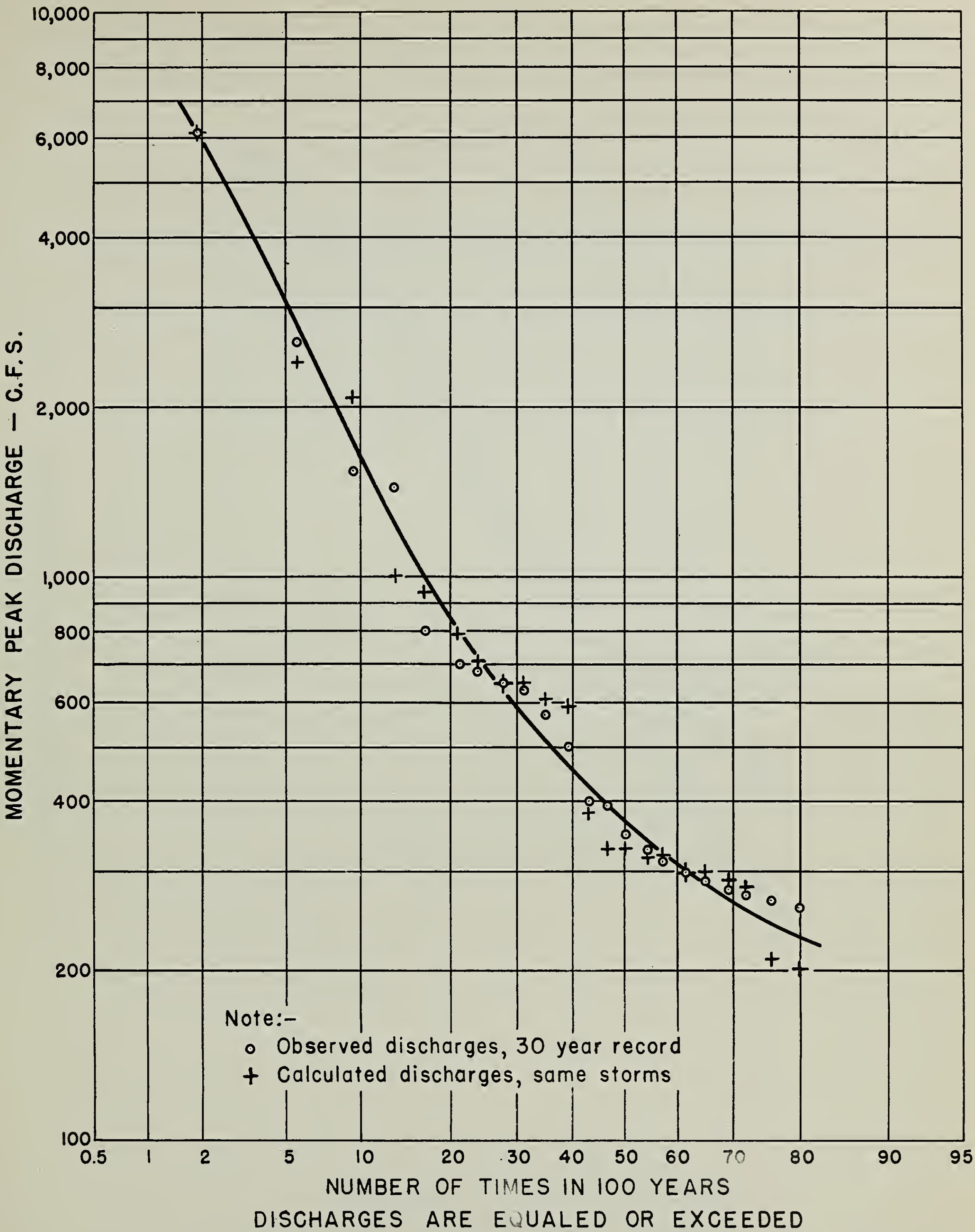
Figure I



BIG SANTA ANITA WATERSHED

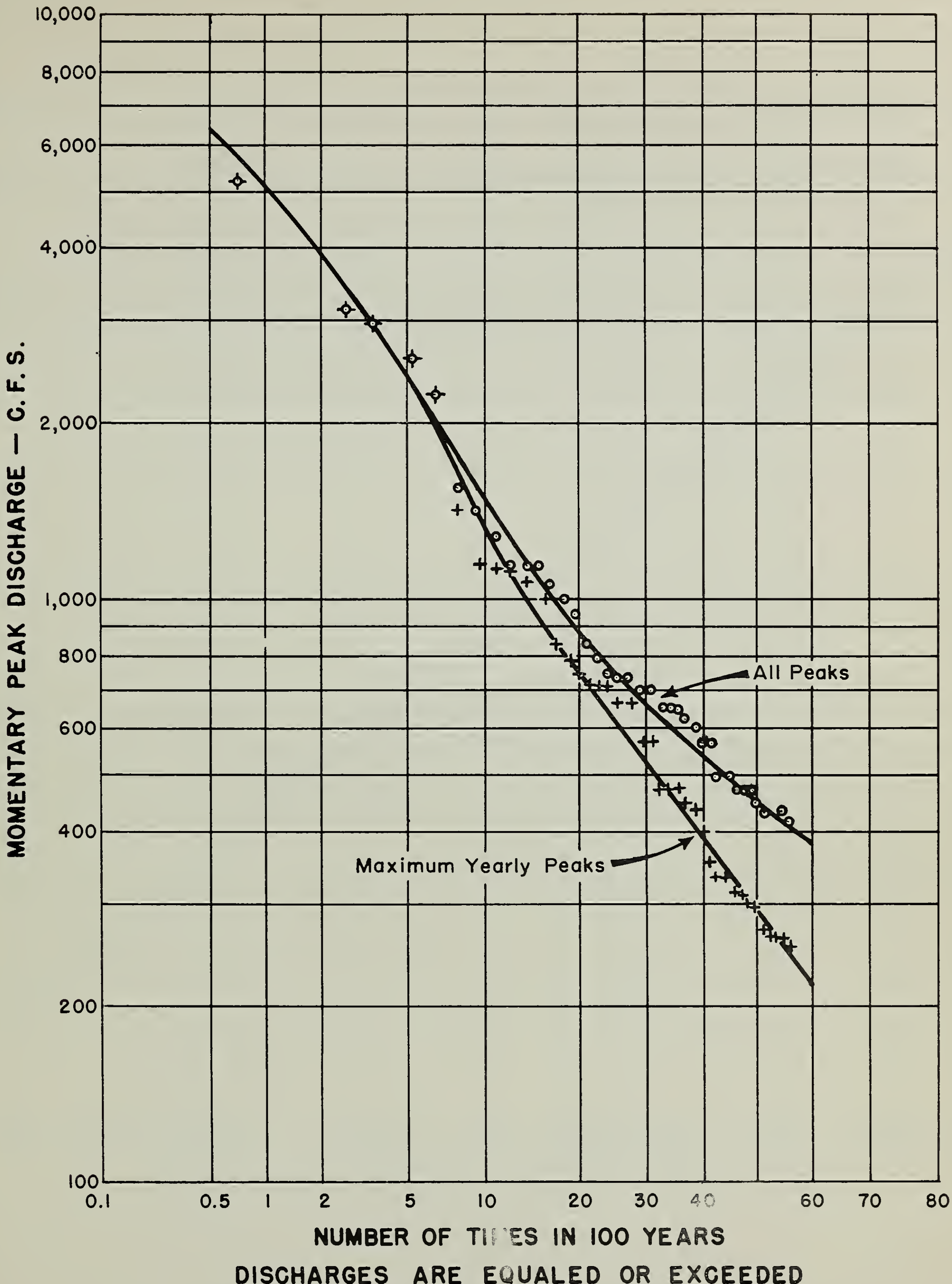
RELATION OF OBSERVED PEAK DISCHARGES
TO COMPUTED DISCHARGES
CALCULATED FROM THE GENERAL EQUATION:–

$$\text{Log } Q = 1.293 + 1.082 \log A + 1.870 \log P_{24} + 0.474 \log aP - 0.852 \log C$$



FREQUENCY CURVE – BIG SANTA ANITA

TEST OF RELATIONSHIP
OF OBSERVED TO CALCULATED PEAK DISCHARGES
BY COMPARISON OF FREQUENCY POINTS

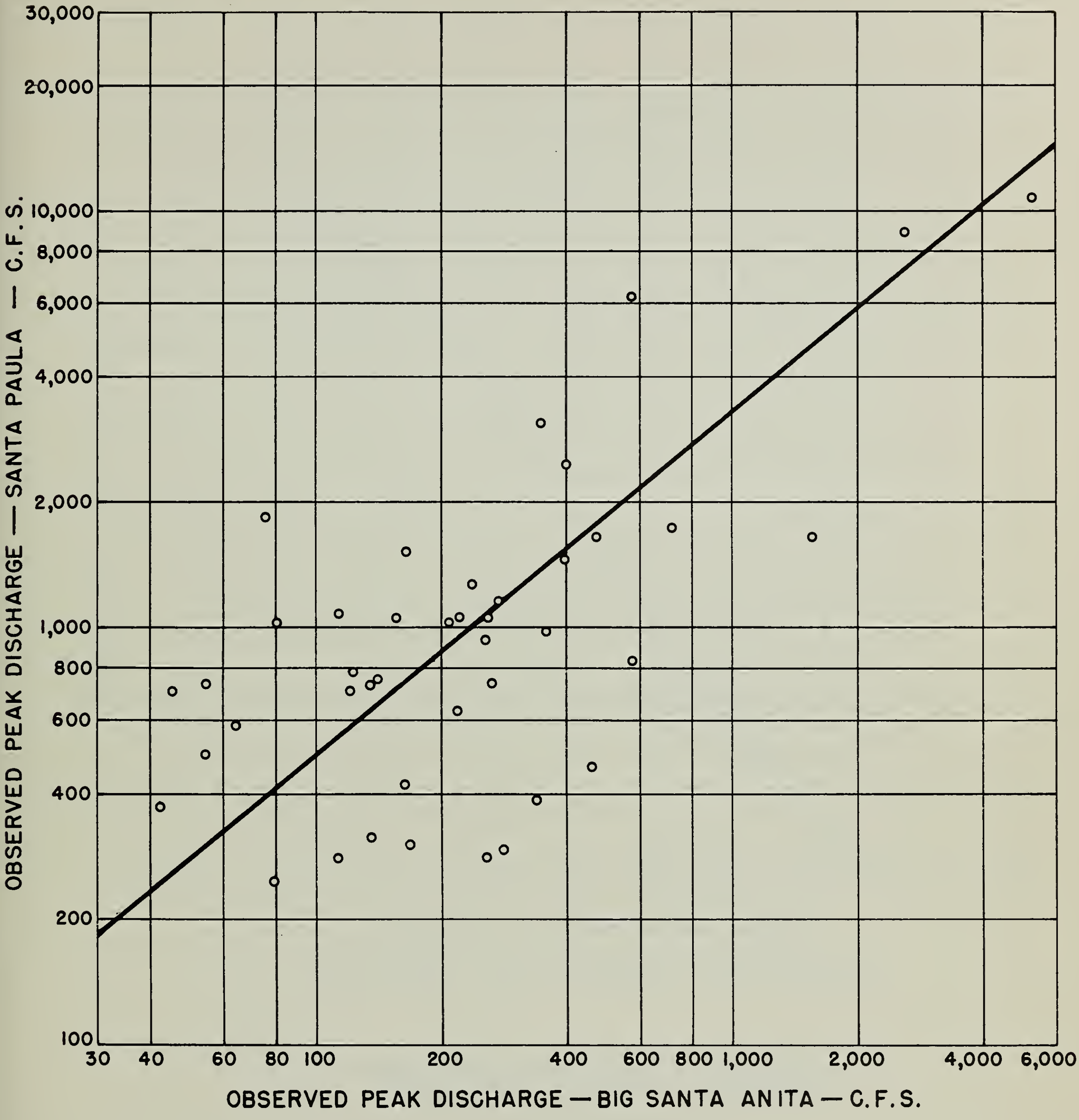


FREQUENCY CURVE—BIG SANTA ANITA

MOMENTARY PEAK DISCHARGES

FOR 40-YEAR OLD VEGETATION

Figure 4

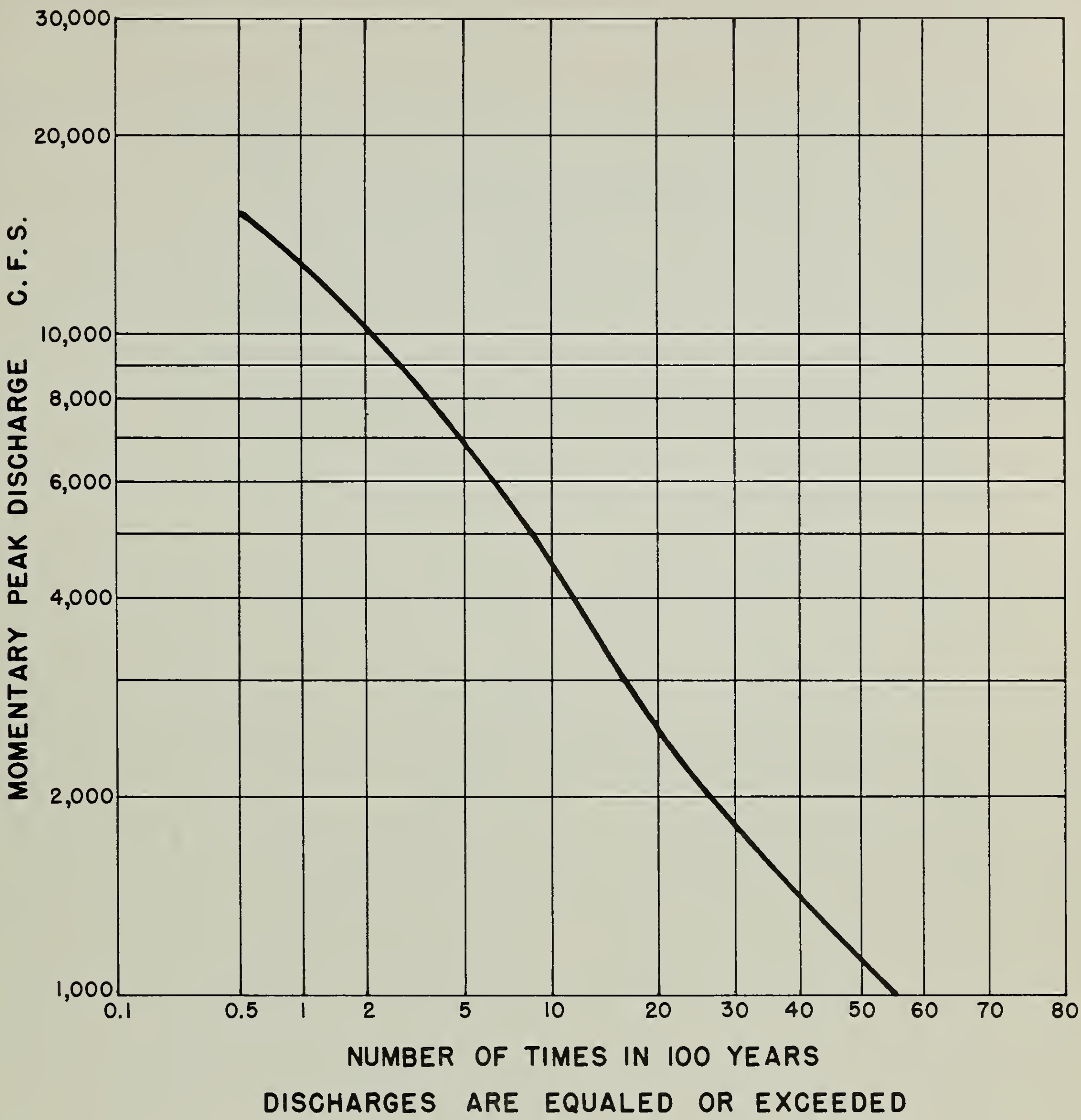


BIG SANTA ANITA — SANTA PAULA

PEAK DISCHARGE RELATIONSHIP FOR SAME STORM FLOWS CORRECTED TO COMMON BASIS OF 40-YEAR OLD VEGETATION

AGRICULTURE - FOREST SERVICE - SAN FRANCISCO

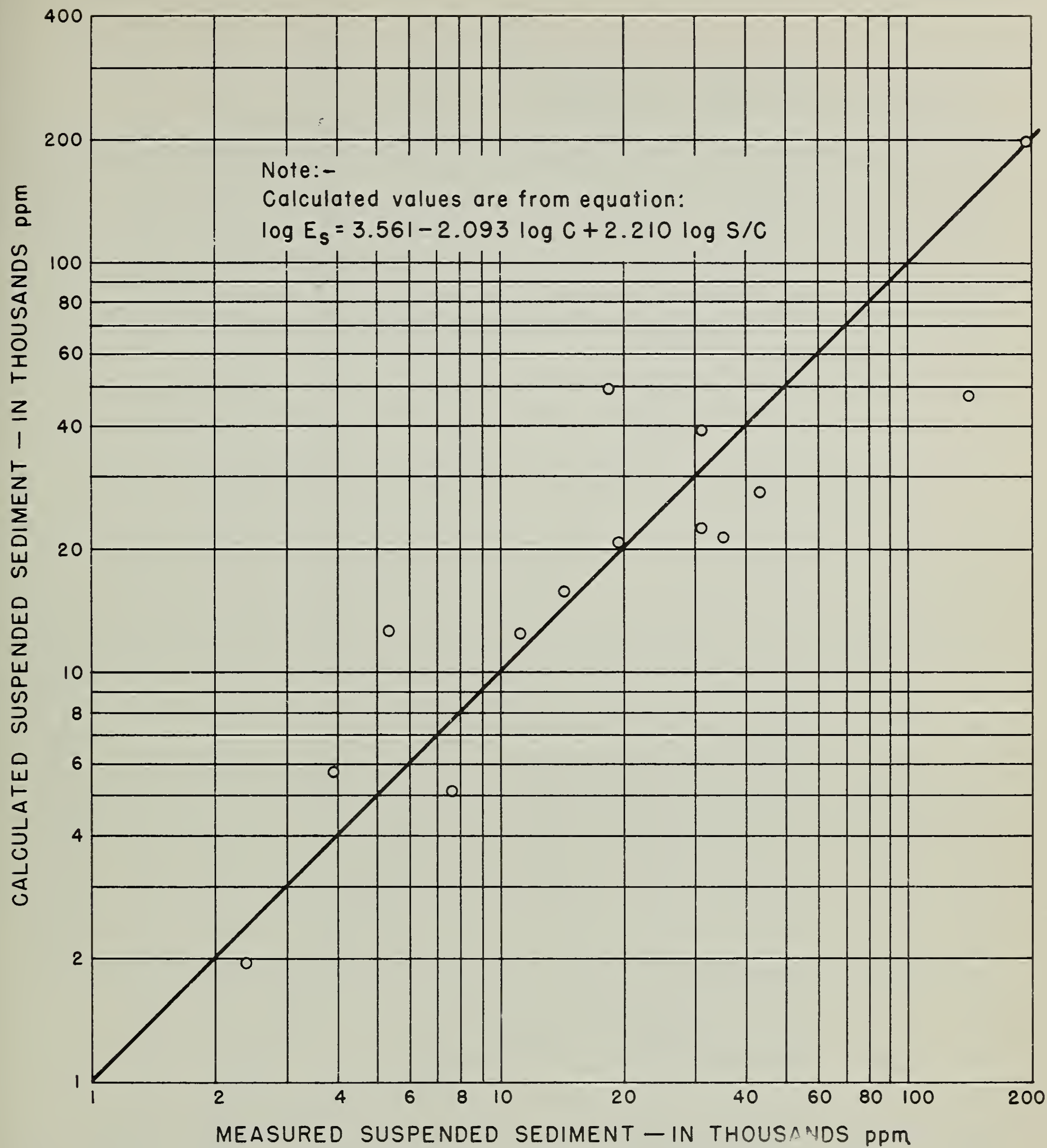
Figure 5



SANTA PAULA CREEK
NEAR
SANTA PAULA, CALIFORNIA

MAXIMUM YEARLY MOMENTARY PEAK DISCHARGES
CORRECTED TO A BASIS OF 40-YEAR OLD VEGETATION

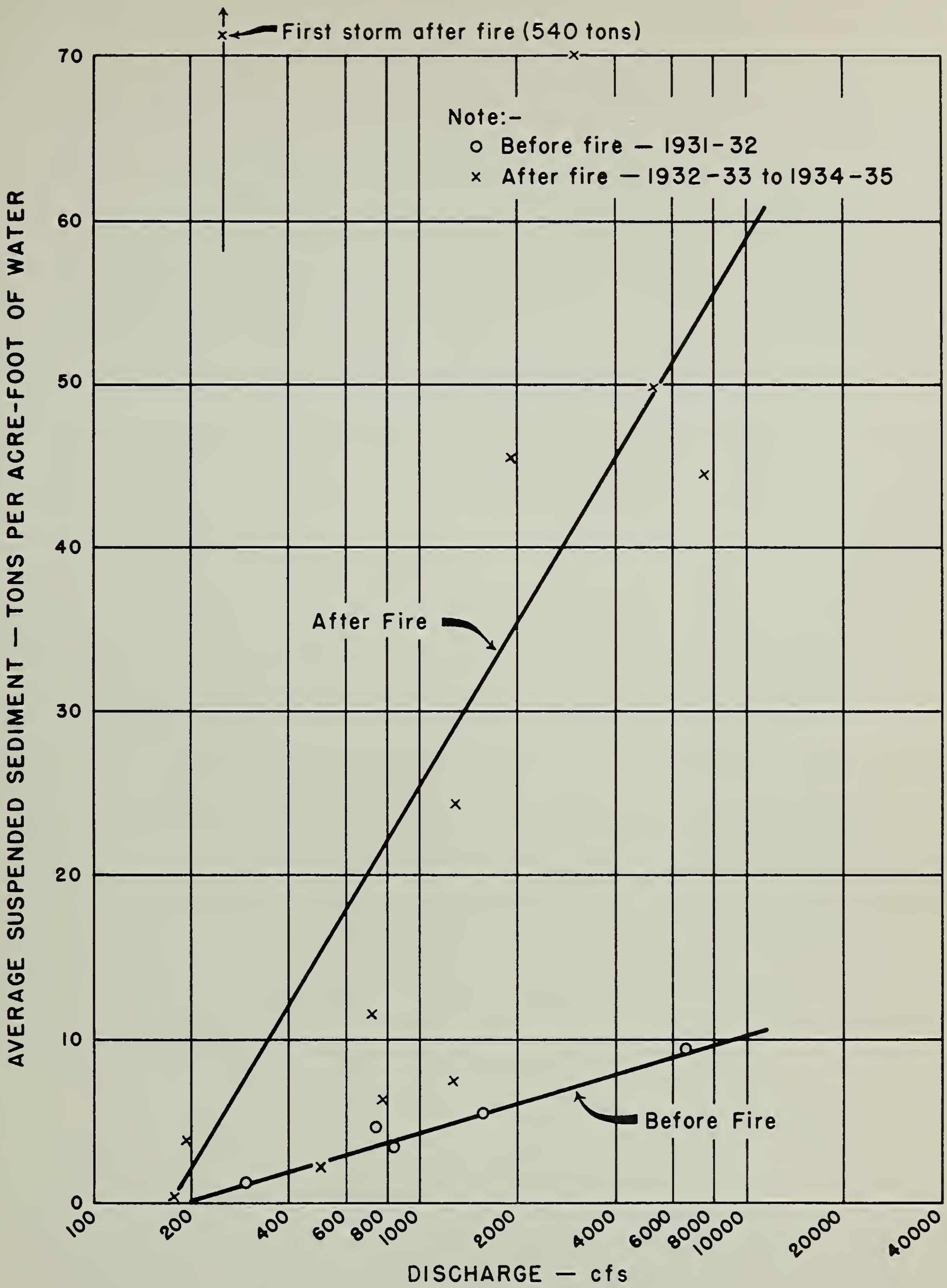
Figure 6



SUSPENDED SEDIMENT

RELATION OF MEASURED TO COMPUTED AVERAGE SUSPENDED SEDIMENT OF STREAMS FOR WATERSHEDS IN AND ADJACENT TO THE SANTA MARIA

Figure 7



SUSPENDED SEDIMENT IN RUNOFF WATER — SESPE CREEK

BEFORE AND AFTER 1932 FIRE

DATA FROM ANNUAL REPORTS
SANTA CLARA WATER CONSERVATION DISTRICT
1931-32 TO 1934-35

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 3

FLOOD AND SEDIMENT DAMAGES

Santa Clara and Ventura Rivers and Calleguas Creek

To accompany report on survey, flood control,
Santa Clara and Ventura Rivers and Calleguas Creek, California

APPENDIX 3

FLOOD AND SEDIMENT DAMAGES

Santa Clara and Ventura Rivers and Calleguas Creek, California

PAST FLOOD DAMAGES

In Appendix 2 the paucity of data on past flood flows is pointed out. Reliable data on flood damages are not available for floods prior to 1938. After the 1938 flood the Corps of Engineers, Los Angeles, made a detailed survey of the damages on the Santa Clara and Ventura Rivers as well as on Calleguas Creek. The damage in these three drainages was about $4,500,000 (table 1) and in its severity to the different types of property was representative of the economic development of the area. On farms, topsoil was eroded, crops destroyed, farm equipment buried under debris or washed away, livestock drowned and fields covered with debris. Land along the rivers, creeks, and barrancas was cut away. The numerous small towns were either inundated or isolated by destruction of roads, bridges, and bridge approaches. Rail communications were interrupted by destruction of the tracks and bridges and by deposition of debris. The destruction caused to the railroad near Saugus in the 1938 flood illustrates the force of this flow. Of eleven bridges in Soledad Canyon only four remained on their foundations, and three of those were buried under debris. About four miles of track were completely destroyed.

Table 1.--Direct damages, Santa Clara River, Ventura River, Calleguas Creek basins, 1938 1/

Property damaged	Santa Clara River	Ventura River	Calleguas Creek	Total
	Dollars	Dollars	Dollars	Dollars
Residential	46,100	54,000	1,500	101,600
Business	40,200	72,300		112,500
Industrial	188,300	162,800		351,100
Agricultural	1,263,700	169,100	126,600	1,559,400
Highways and bridges	1,254,200	272,500		1,526,700
Railroads and bridges	600,000	2,800	13,200	616,000
Utilities	63,300	16,200		79,500
Communication systems	27,200	15,100		42,300
Channel improvement	42,000	--	11,800	53,800
Miscellaneous	30,000	12,000		42,000
Total	3,555,000	776,800	153,100	4,484,900

1/ 1938 values and prices.

After the floods of 1943 and 1944 the Corps of Engineers again made detailed damage surveys. The damages are given in table 2. It should be noted that although the discharge of 1944 was smaller than in 1943 damage was higher. Dikes were weakened in 1943 and broke in 1944. Also the Santa Clara River meandered more in its lower portion during the latter year and destroyed more land.

Table 2.--Direct damages:Santa Clara River floods of January 1943 and February 1944 1/

Property damaged	Direct damages 1943	Direct damages 1944
	Dollars	Dollars
Agriculture	145,000	300,000
Railroads and bridges	75,000	150,000
Highways and bridges	15,000	170,000
Industries	13,500	
Utilities	--	60,000
Channel improvements	80,000	70,000
Miscellaneous	5,000	--
Total	333,500	750,000

1/ Values as of year when damages occurred.

ESTIMATED FUTURE FLOOD DAMAGES BY DRAINAGE AREAS

The damage data from the 1938, 1943, and 1944 floods have been used for estimating future damages. Estimate of future flood damages was made for each area for at least three flood sizes. They form the basis for the damage discharge curves which are essential in the calculation of future average annual damages. Description of damages by drainage areas are presented in the following pages. Values given represent prices as they prevailed during the first half of 1948.

A. Santa Clara Basin

1. The Santa Clara River and Tributaries Above Piru Creek.--The greatest concentration of damages is in Soledad Canyon where both transcontinental highways and railroads skirt across and recross the river. Ranches and recreational areas also are hard hit by floods. In other tributary canyons the threat is greatest to roads, power and pipelines, recreational areas, and to the scattered agricultural land. Distribution of damages for a flood of 24,000 c.f.s. on Santa Clara River at Saugus and estimated total damages for two other flood sizes are:

Table 3.--Damages: Santa Clara River and tributaries above Piru Creek

Type of properties	Damages		
	Direct	Indirect	Total
	Dollars	Dollars	Dollars
Residences and cabins	117,800	12,100	129,900
Agriculture	279,000	28,000	307,000
Business	67,600	10,100	77,700
Industry	16,500	1,500	18,000
Highways and bridges	1,181,000	230,000	1,411,000
Railroads and bridges	1,069,700	253,000	1,322,700
Camps and recreation grounds	7,000	0	7,000
Transmission and communications	109,000	25,000	134,000
Pipelines	81,000	24,000	105,000
Total for discharge of 24,000 c.f.s. at Saugus	2,928,600	583,700	3,512,300
Other discharges			
12,000 c.f.s.			702,500
5,000 c.f.s.			1,000

2. Santa Clara River Below Piru Creek Exclusive of the Oxnard Plain.--This includes the area between Piru Creek and the west end of South Mountain and the area below South Mountain not to be protected by the authorized Corps of Engineers improvements.

Since the valley floor within this reach of the river is largely agricultural in character, farm damages predominate. Except for a small area near Bardsdale at the river's junction with Sespe Creek most of the valley land is located on the right bank and is in irrigated orchards, truck crops, beans, and pasture. Loss from scouring and bank cutting is heavy and represents the major damage. Land ruined by large floods may lie idle for years and revert to brush. After a period of relatively low flows or after construction of revetments give some degree of safety it will be put under cultivation again. The only towns affected directly by waters from the Santa Clara River above the authorized Corps of Engineers' dikes are Santa Paula and Fillmore. However, residential properties are scattered throughout the valley. Distribution of damages is shown in table 4.

Table 4.--Damages: Santa Clara River below Piru Creek 1/

Type of property	Damages Direct	Indirect	Total
	Dollars	Dollars	Dollars
Residences	379,700	47,600	427,300
Business	47,600	7,500	55,100
Industry	46,900	11,600	58,500
Agriculture	2,632,900	314,400	2,947,300
Highways	153,700	77,500	231,200
Railroads	10,700	10,900	21,600
Utilities	34,000	9,800	43,800
Channel improvements	142,200	0	142,200
Public property	117,600	23,700	141,300
Total for discharge of 210,000 c.f.s. at Montalvo	3,565,300	503,000	4,068,300
Other discharges			
110,000 c.f.s.			1,518,000
53,000 c.f.s.			547,000
21,000 c.f.s.			160,000

1/ Includes only those areas not to be protected by the authorized Corps of Engineers improvements.

3. Lower Piru Creek.--The town of Piru, a short stretch of highway, railroads, and a small area of agricultural land are the only important properties subject to damage on the short cone of Piru Creek. Distribution of damages is shown in table 5.

Table 5.--Damages: lower Piru Creek

Type of property	Damages Direct	Indirect	Total
	Dollars	Dollars	Dollars
Residences	48,300	8,500	56,800
Business	6,400	1,000	7,400
Industry	14,200	2,800	17,000
Agriculture	50,100	6,700	56,800
Highways and bridges	35,500	7,100	42,600
Railroads and bridges	9,900	2,000	11,900
Utilities	50,000	15,900	65,900
Total for 54,000 c.f.s. discharge	214,400	44,000	258,400
Other discharges			
30,000 c.f.s			160,000
15,000 c.f.s.			75,300

4. Lower Sespe Creek.--Citrus orchards cover most of the land on lower Sespe Creek. The town of Fillmore is endangered by flow from Pole Canyon and the river. It would also be severely damaged by large flows from Sespe Creek and whenever the creek changes its course to the east side of the cone. Expected damages for various discharges are shown in table 6.

Table 6.--Damages: Lower Sespe Creek

Type of property	Damages		
	Direct	Indirect	Total
	Dollars	Dollars	Dollars
Residences	144,800	22,700	167,500
Business	5,700	1,400	7,100
Agriculture	409,000	62,500	471,500
Highways and bridges	41,200	10,000	51,200
Railroads and bridges	8,500	2,800	11,300
Utilities	35,500	11,400	46,900
Public properties	12,800	2,800	15,600
Total for discharge of 80,000 c.f.s.	657,500	113,600	771,100
Other discharges			
60,000 c.f.s			403,300
40,000 c.f.s.			35,500

5. Santa Clara River Barrancas and Small Tributaries.--Along the north side of the river barrancas drain the hillsides and cut deeply into the citrus-covered slopes. Some of these have reached a depth of 50 feet and are as much as 100 feet wide. Others are only starting to make their appearance. The older barrancas are partially stabilized at crossings but much valuable land continues to be lost by slumping and side cutting. The threat of fallen trees clogging gully plugs at road crossings is ever present with resulting cuts in roads and land loss. The newer barrancas generally have not cut much below Foothill Boulevard. Flows from them spread over citrus orchards and leave deep deposits of debris and sand around the trees. Above Santa Paula some of the smaller tributaries to the river have formed large cone areas and are depositing great quantities of debris which cause shifting of the creek course as they traverse farm land or small urban developments. A similar condition exists on the north side of the river near Bardsdale.

Damages are given for these tributaries and barrancas separately for the areas between the large tributaries Santa Paula, Sespe, and Piru Creeks.

Table 7.--Damages: Santa Clara River Barrancas and Small Tributaries

Type of property	Damages: Direct	Damages: Indirect	Damages: Total
	Dollars	Dollars	Dollars
From Harmon Canyon to Santa Paula Creek			
Buildings	6,000	1,000	7,000
Agriculture	219,000	20,000	239,000
Roads	67,000	18,000	85,000
Channel improvements	1,000	0	1,000
Total for discharge corresponding to 16,000 c.f.s. on Santa Paula Creek	293,000	39,000	332,000
From Santa Paula Creek to Sespe Creek			
Buildings	3,000	500	3,500
Agriculture	106,500	10,000	116,500
Roads	19,100	5,000	24,100
Channel improvements	1,000	0	1,000
Total for discharge corresponding to 16,000 c.f.s. on Santa Paula Creek	129,600	15,500	145,100
From Sespe Creek to Piru Creek (including Bardsdale area)			
Residences	35,000	7,000	42,000
Industry	17,500	3,500	21,000
Agriculture	121,400	18,200	139,600
Highways	24,100	7,200	31,300
Railroads	3,000	600	3,600
Utilities	3,500	400	3,900
Public properties	6,100	0	6,100
Channel improvements	13,100	0	13,100
Total for discharge corresponding to 39,000 c.f.s. on Piru Cr.	223,700	36,900	260,600

Others with discharges corresponding to:

	Harmon Canyon to Santa Paula Creek	Santa Paula Creek to Sespe Creek	Sespe Creek to Piru Creek
	Dollars	Dollars	Dollars
Santa Paula Creek			
7,000 c.f.s.	138,000	61,000	
1,800 c.f.s.	7,000	2,000	
Piru Creek			
16,000 c.f.s.			106,000
3,700 c.f.s.			4,000

B. Ventura River Basin

1. Ventura River Including Lower Coyote Creek above the Corps of Engineer's Levee.--The Corps of Engineers has constructed a levee below Ventura Avenue oilfields to protect the city of Ventura. The damageable properties above this point are oil and associated industries and business, the rather limited agricultural area along the river, and roads. Table 8 gives a summary of damages that may be expected with different discharges.

Table 8.--Damages: Ventura River above Corps of Engineer's levee

Type of property	Damages: Direct	Damages: Indirect	Damages: Total
	Dollars	Dollars	Dollars
Residences	46,500	8,300	54,800
Industry and business	303,200	91,000	394,200
Agriculture	163,700	16,400	180,100
Highways and roads	171,100	53,300	224,400
Railroads	1,900	200	2,100
Electric systems	1,900	200	2,100
Telephone systems	3,700	400	4,100
Total for discharge of 39,200 c.f.s. below Coyote Creek	692,000	169,800	861,800
Other discharges			
20,000 c.f.s.			300,000
2,000 c.f.s.			57,000

2. Horn, Senor, and San Antonio Creeks.--Stewart, Senor, and Horn are the major tributaries to San Antonio Creek. After leaving the Ojai Valley, San Antonio Creek flows through a very narrow valley, without significant development, into the Ventura River. Stewart Canyon debouches from the mountains directly into the town of Ojai. Because of the great damage potential the Corps of Engineers proposes construction of a debris basin and channel on this stream. Horn Canyon may spread over a relatively wide cone area of the Ojai Valley, but Senor has been confined by an improved channel. Estimates of damages for several discharges are given in table 9.

Table 9.--Damages: Horn and San Antonio Creeks

Type of property	Damages: Direct	Damages: Indirect	Damages: Total
	Dollars	Dollars	Dollars
Residences	2,800	600	3,400
Business	3,000	1,000	4,000
Agriculture	83,600	8,400	92,000
Roads and bridges	35,300	7,000	42,300
Total for flood corresponding to 12,200 c.f.s. on Matilija Creek	124,700	17,000	141,700
Other discharges			
10,000 c.f.s. on Matilija Creek			100,000
5,000 c.f.s. on Matilija Creek			17,500

C. Calleguas Creek Basin Including Las Posas Creek

1. Calleguas Creek Below Moorpark.--Calleguas Creek below Moorpark traverses walnut and deciduous fruit orchards, land in truck crops, beans, and pasture. In its course through the Oxnard Plain dikes protect land predominantly in beans and sugar beets. Damage is mainly to agricultural properties, and loss from bank cutting outweighs all others. The damages presented in table 10 are based upon a study previously made by the Corps of Engineers.

Table 10.--Damages: Calleguas Creek below Moorpark

Type of property	Damages: Direct	Damages: Indirect	Damages: Total
	Dollars	Dollars	Dollars
Agriculture	256,300	42,600	298,900
Roads and bridges	67,900	15,100	83,000
Channel improvements	38,700	0	38,700
Total for discharge of 10,500 c.f.s. at Moorpark	362,900	57,700	420,600
Other discharges			
6,000 c.f.s.			195,000
3,000 c.f.s.			18,500

2. Tributaries to Calleguas Creek Above Confluence with Conejo Creek.--Great damage is done by small tributaries to Calleguas Creek. They carry large amounts of debris and deposit it upon entering the plain.

In many instances there exist no channels between Calleguas Creek and the slopes. Orchards are being ruined and roads and railroads covered with sand and debris. The course of the lower tributaries is generally well defined. These are of a barranca type and damage is predominantly to citrus orchards caused by bank cutting or caving of the steep banks. Damages from the important tributaries and barrancas are given in table 11.

Table 11.--Damages: Upper Calleguas Creek and tributaries above Conejo Creek

Type of property	Damages: Direct	Damages: Indirect	Damages: Total
	Dollars	Dollars	Dollars
Agriculture	126,400	2,500	128,900
Residences and buildings	37,500	4,800	42,300
Roads	28,900	6,000	34,900
Railroads	26,100	500	26,600
Industry	30,000	1,500	31,500
Channel improvements	10,000	0	10,000
Recreation areas	2,500	0	2,500
Total for discharge corresponding to 2,000 c.f.s. on Gabbert Canyon	261,400	15,300	276,700
Other discharges			
1,000 c.f.s.			121,700
500 c.f.s.			38,700

3. Conejo Creek and Barrancas.--The land of the overflow area of lower Conejo Creek is mostly used for bean growing. Damage is mainly from inundation. In the upper part the land is in citrus orchards, alfalfa, and other irrigated crops. For about one and one-half miles, Santa Rosa Creek is without a defined channel. Damage is greatest at this point and just above it. Small side tributaries deposit debris and flood citrus orchards, irrigated cropland, bean land, and roads.

Damage estimates for Conejo Creek are shown in table 12.

Table 12.--Damages: Lower Conejo Creek

Type of property	Damages: Direct	Damages: Indirect	Damages: Total
	Dollars	Dollars	Dollars
Agriculture	125,800	14,000	139,800
Roads and bridges	19,100	6,200	25,300
Total for discharge of 4,200 c.f.s.	144,900	20,200	165,100
Other discharges			
3,000 c.f.s.			88,500
1,000 c.f.s.			2,600

4. Las Posas Wash.--The upper tributaries of Las Posas Wash are of a barranca type. On their way to the valley land is lost through undercutting of the banks and fingering gully erosion. Very heavy road damage and sedimentation of cropland occurs where tributaries skirt the highway. The wash continues in its course through irrigated cropland and walnut orchards. As it enters an area of dry-farmed land it cuts to a depth of about 70 feet into the old valley fill. Cropland is lost through undercutting and sloughing off of banks. The wash carries a heavy load of silt and sand which is deposited upon bean land of the Oxnard Plain. The floodwaters finally drain off into Revelon Slough. Small tributaries from the Camarillo Hills add further to the damage in the Oxnard Plain.

Estimates of damages are given in table 13.

Table 13.--Damages: Las Posas Wash

Type of property	Damages: Direct	Damages: Indirect	Damages: Total
	Dollars	Dollars	Dollars
Agriculture	207,000	10,000	217,000
Roads	111,000	20,000	131,000
Channel improvements	6,000	0	6,000
Total for discharge corresponding to 10,000 c.f.s. on Calleguas Creek	324,000	30,000	354,000
Other discharges			
6,000 c.f.s.			205,000
2,500 c.f.s.			49,500

AVERAGE ANNUAL DAMAGES

Estimates of damages from individual future floods by discharges given in tables 3 to 13 are used as the basis for preparation of the damage discharge curves. The frequencies of these discharges are discussed in Appendix 2 and given in table 5 of that appendix for certain control points. From these data discharge frequency curves are prepared. A combination of these two sets of data gives the damage frequency curve. The average annual damage is then obtained either by planimetering or tabulating the area under the damage frequency curve and dividing by 100. An example of the latter method for Piru Creek is given below. The stub of table 14 gives the midpoints of frequencies by which given floods are equalled or exceeded. Column 1 is discharges obtained from table 5, Appendix 2. They are based on the discharges given in that table, columns 2, 3, 4, and 5 multiplied by the factor in column 10 which converts discharges expected under "present" watershed conditions to those expected under watershed conditions without a program.

Table 14.--Average annual damages: Piru Creek

Frequency	Discharge	Damage	Damage times number of events
	C.f.s.	Dollars	Dollars
.5	47,000	237,000	237,000
1.5	38,400	200,000	200,000
2.5	28,600	153,000	153,000
3.5	24,800	132,000	132,000
4.5	20,000	105,000	105,000
7.5	15,600	80,000	400,000
15.0	9,900	47,000	470,000
25.0	6,800	32,000	320,000
Total			2,017,000
Average annual			20,200

Similar calculations were made for all of the areas for which damage estimates are shown in tables 3 to 13. The resultant average annual damages are given in table 15.

Table 15.--Average annual damages: Santa Clara, Ventura, and Calleguas drainages, exclusive of damages to be prevented by existing flood-control structures

Area	Average annual damage
	Dollars
Santa Clara River and tributaries above Piru	514,300
Santa Clara River between Piru and South Mountain	299,000
Piru Creek	20,200
Sespe Creek	22,900
Santa Clara River, barrancas, and small tributaries	55,100
Ventura River to levee	94,800
Horn and San Antonio Creek	14,700
Calleguas Creek below Moorpark	19,900
Tributaries to Calleguas Creek above Conejo Creek	19,600
Conejo Creek	6,300
Las Posas Creek	21,100
Total	1,087,900

The average annual damage in the three drainages now unprotected or for which no protection is at present contemplated by Federal or local agencies is $1,087,900. To this must be added damage to future development. To obtain an estimate of future development, advantage is taken of the parallel trends between economic and population growth.

Population of Ventura County has increased from 70,000 in 1940 to an estimated 103,000 in 1950. It is estimated that by 1960 the population will increase to 146,000. 1/ For the period after 1960 it is assumed that the trend predicted by Yeatman 2/ in 1935 for 1950 to 1960 would

1/ William A. Spurr. Forecast of California's population and production, 1950-1960. Stanford University, California, 1949.

2/ W. C. Yeatman. California population estimates to 1960. Los Angeles, California, 1935.

be resumed and that population growth would practically come to an end by the year 2000.

The total increase between 1950 and 2000 is estimated at 101,000 or nearly 100 percent.

Based upon the population increase of the towns of Ventura, Oxnard, and Santa Paula during the past decade, 80 percent of future population increase would take place in or around these cities. Since flood protection has been provided or is authorized for these areas only 20 percent of the increase would affect unprotected areas.

When average annual damages are multiplied by 20 percent of the annual rate of increase and discounted to the present, the average annual damages due to future development should be increased by 14 percent.

The average annual damages for areas not now protected or for which no protection is planned at present by other agencies is $1,240,200.

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 4

PLAN OF IMPROVEMENT

Santa Clara and Ventura Rivers and Calleguas Creek

To accompany report on survey, flood control,
Santa Clara and Ventura Rivers and Calleguas Creek, California

APPENDIX 4

PLAN OF IMPROVEMENT

Santa Clara and Ventura Rivers and Calleguas Creek

INTRODUCTION

The recommended remedial program to reduce flood damage in the Santa Clara group of streams consists of a series of interdependent measures to be installed over a period of 20 years. The structural and cultural measures are integrated to secure a significant reduction in flood damages by reducing flood peaks, erosion, and sedimentation. The remedial measures also provide substantial conservation benefits.

The determination of the quantity of needed measures for the intensification of the present program for both flood control and conservation of watershed lands was made by consideration of total needs and projection of anticipated accomplishment by existing conservation programs.

PLAN OF IMPROVEMENT

The measures recommended to accomplish reduction in floodwater and sediment damages are given below and are discussed separately.

Measures for the stabilization and improvement of the watershed include:

1. Intensified fire prevention and control.
2. Land acquisition.
3. Range improvements, including gully control.
4. Valley community channel improvements.
5. Farm runoff disposal.
6. Seeding to perennial grasses areas unsuitable for crops.
7. Irrigation system improvements for erosion control.
8. Terrace and diversion systems.

1. Intensified Fire Protection and Control

The unusually long dry season, the steep terrain, the high inflammability of the natural cover, and heavy recreational use combine to make southern California watersheds one of the most difficult fire-control problems in the United States. The need for adequate fire protection is emphasized by the proximity of destructible recreational, urban, and agricultural developments tributary to the high-hazard areas. It is significant that in the organic act of setting up national forests in southern California the primary objective was "to insure favorable conditions of water flows." Rates of burn have varied widely by individual years. The present average annual rate of burn is estimated to be 2.04 percent for the high-hazard

Revised May 1952

zone. This zone is composed of the area within the national forest protection zone in the Ventura, Sespe, San Francisquito, Bouquet, and Castaic drainages, and totals about 656 square miles. In the medium-hazard zone in the area within the national forests the present average annual rate of burn is 1.37 percent. The rate for the medium-hazard zone protected by Los Angeles and Ventura Counties is 1.25 percent. The total area classified as medium-hazard contains 1,169 square miles.

The future rate of burn was estimated from Forest Service records of use of the wildlands, from predicted trends of future use, and from past relations between fire occurrence and number of users. Future use can be expected to increase greatly because of increased population in the report area and the consequent increase in recreational requirements.

Forest Service use records are not available on a watershed basis, but the statistics for Los Padres National Forest are considered representative of the increasing use of the Ventura-Santa Clara River watersheds. For this Forest the number of all classes of users by periods was:

1911-1925 (average annual for period)	9,870
1926-1930 (average annual for period)	68,500
1935	109,500
1940	244,000
1945 (restricted use during war years)	135,500
1949	305,000

A related problem peculiar to the wildland area involves the heavy use of the forest lands during the hunting season, which at present is coincident with the period of highest fire danger.

As a result of the increased development and population growth discussed in Appendix 1 a conservative estimate of future annual use is about 360,000. Past experience shows that increased use invariably resulted in an increased number of fires regardless of the prevailing prevention effort. For Los Padres Forest the number of fires occurring in relation to use was:

Year	Average annual number of users	Average number of man-caused fires	Number of users per man-caused fire
1911-25	9,870	19.5	506
1926-30	68,500	21.2	3,231
1931-35	96,360	25.2	3,823
1936-40	192,710	25.0	7,708
1940-45	(Inadequate records)		
1947-49	267,180	27.0	9,895

From these records, it is to be expected that for every 10,700 users in the near future there will be at least one fire.

Analysis of these data indicates that (1) the estimated 360,000 annual users will bring about an incidence rate of one fire for every 10,700 users; (2) this rate will in turn cause about 33 fires annually under the present level of protection; and (3) this number of fire starts will increase the average annual rate of burn to about 3 percent. For purposes of program evaluation this projected rate of burn was used, rather than the current rate.

The flood-control objective is to reduce the average annual rate of burn to .2 of 1 percent. Based on the present and expected rates of burn with and without the intensified program , the frequency of major dis-disastrous fire occurrences can be reduced.

Measures necessary to accomplish the objective fall into two categories, preventive measures and control measures. Preventive action is aimed at reducing the number of starts by intensifying and expanding hazard reduction and educational programs. Control measures have as a major objective the quick detection and suppression of all fires. This is now accomplished by lookouts supplemented by aerial patrol and specially trained and equipped suppression crews readily available for initial attack on fires. The methods and facilities for fire protection and control are constantly improving; consequently, any proposed plan cannot be considered static but must be flexible to meet changing conditions and to utilize new techniques and devices.

Additional facilities will include about 660 miles of construction and reconstruction of roads and trails at an initial cost of $1,950,800 There is a need for 168 new buildings at a cost of $1,859,800. Detection and communication will require 192 new units at a cost of $176,100. New pieces of equipment, trucks, tankers, tractors, etc. to the extent of 66 units, costing $340,800, are needed. A total of 175 protection and suppression personnel are needed over and above present levels, including patrolmen, tank truck and tractor operators, air crews, and similar technicians. The estimated annual cost for increased personnel is about $276,400. About 67 additional water improvements consisting of tanks, springs, catchment basins, sumps, and similar improvements will be required to facilitate fire suppression. The total average annual operation, maintenance cost of the fire control measures is $499,200.

Total installation costs for the recommended fire protection measures by agencies responsible for current fire protection in the area are shown in table 1. Annual operation and maintenance costs are shown in table 1-a. The recommended distribution costs between Federal and non-Federal sources is shown in Appendix 5.

Revised May 1952

Table 1.--Quantities and installation costs: recommended fire-control program

Measure	Unit	National forest No.	National forest Cost	Ventury County No.	Ventury County Cost	Los Angeles County No.	Los Angeles County Cost	Total No.	Total Cost
			Dollars		Dollars		Dollars		Dollars
Roads and trails	Mi.	606	1,411,900	42	478,000	12	60,900	660	1,950,800
Buildings	No.	126	1,001,200	34	661,900	8	196,700	168	1,859,800
Detection and communication	No.	100	73,400	50	50,200	42	52,500	192	176,100
Equipment	No.	44	129,100	13	73,100	9	138,600	66	340,800
Water developments	No.	47	120,500	10	3,200	10	25,000	67	148,700
Total			2,736,100		1,266,400		473,700		4,476,200

Table 1-a.--Annual operation, maintenance, and replacement costs: fire-control program

Measure	National forest	Ventura County	Los Angeles County	Total
	Dollars	Dollars	Dollars	Dollars
Roads and trails	26,000	3,400	11,000	40,400
Buildings	40,800	36,800	10,000	87,600
Detection and communication	6,600	5,700	4,300	16,600
Equipment	23,100	17,900	27,700	68,700
Water development	3,800	700	5,000	9,500
Personnel 1/	164,400	62,000	50,000	276,400
Total	264,700	126,500	108,000	499,200

1/ The additional personnel would be mostly seasonal employees. They are divided: National forest, 121; Los Angeles County, 30; Ventura County, 24.

The treatment of new burns is an essential emergency measure to guard against excessive damage from the inevitable fires that will occur regardless of the intensity of protection. The number of large fires and the total burned area can be reduced but complete elimination of all fires cannot be expected. Such emergency measures are considered an integral part of the recommended plan.

2. Land Acquisition

As an aid to accomplishing satisfactory cover maintenance and erosion control in the interest of flood control, public acquisition of certain lands is recommended. The acquisition of this land would also provide for better management and fire control. There are 2,810 acres of private land within Los Padres National Forest which are so located that use by private individuals constitutes a threat to very valuable watershed lands. These scattered parcels range in size from 20 to 160 acres. Some are eroding range lands or brush land with widely scattered grass whose continued operation is economically marginal. A few parcels are cultivated and put into grain each year. They produce a poor crop and should be retired from cultivation in order to stop soil movement. Most of the acreage is in areas of high inflammability and high water production importance.

Continued private use of these pieces of land or attempts to improve the land by removal of brush by fire is a danger to fire prevention efforts on the large blocks of public wild lands. Their acquisition would reduce the fire prevention problem and decrease the possibility of watershed denudation. It is estimated that the acquisition of this land will cost about $47,200.

3. Range Improvements

Livestock are grazed upon about one-half of the area of the three watersheds. The condition of the land used by livestock is extremely poor. Until recent years practically no consideration was given the range by livestock raisers using it. Range was used year-long and as heavily as was possible to produce cattle of feeder condition. In recent years close study 1/ has been given by the Soil Conservation Service to range areas of the Quail Lake Soil Conservation District. The results of this study have been used extensively in preparing a program of remedial measures for grazing land, particularly in the wild-land areas.

Overgrazing over a long period of time has greatly reduced the density and quality of the vegetation for range use and consequently the carrying capacity. At present at least two-thirds of the range lands would be classified from "fair" to "very poor." Obviously, the land is producing but a fraction of the forage potential of which it is capable.

1/ Peter W. Taylor. Range condition. Quail Lake Soil Conservation District, June 1947.

While the loss of carrying capacity under present management is very great, a more important loss to the public generally is that caused by erosion and flash floods. Loss of vegetative cover, lack of plant residue, and impaction of soil by trampling during wet weather have greatly reduced the infiltration capacity of the soil. The program recommended plus expected accomplishments of current programs, will provide for stabilization of the soil, increase infiltration capacity, and through improved livestock management practices increase the carrying capacity of the range land areas and the amount of beef produced.

A program of gully stabilization is proposed for the range area of greatest accelerated erosion, the headwaters of Piru Creek. In this area erosion has progressed to the point where gullies ranging from shallow to 20 feet deep have been created in the mountain meadows and best grass areas. Some gullies are so deep they are more properly described as valley trenching. Complete or even partial reclamation of the worst portions is a long term expensive undertaking. Solely on the basis of reclaimable forage some of the required work would not be justified. There are sites for water conservation reservoirs on Piru Creek below the area discussed. When these reservoirs are constructed there will be a public interest in arresting debris movement from the large spectacular gullies. The work proposed at this time is the stabilization of the less severe erosion for the purpose of reclaiming and improving valuable range lands. Nevertheless, the major gullies described represent extreme watershed deterioration and this problem must be faced in the near future.

The gully control work in the Upper Piru area will include bank sloping and planting, temporary barriers and gully plugs, and temporary fencing to protect the banks until stabilized. This work should raise the water table and fix the gradient of the meadowland drainage, and facilitate the planned reseeding to perennial grasses.

Below is given a summary of the management and "structural" provisions of the total program required under current and flood-control plans:

1. Adjust livestock numbers to carrying capacity of range.

2. Practice a system of deferred and rotation grazing.

3. By fencing, water development, salting, and herding, secure uniform utilization of the range.

4. Change highly eroded clean cultivated field to permanent pasture.

5. Gully control in the headwaters of Piru Creek.

6. Fence to exclude stock from areas where gullies are being treated and from steep slopes which cannot be revegetated unless completely protected.

7. Convert low-value annual grass and sagebrush ranges to perennial grass, either native or introduced species.

8. Encourage stockmen to:

   a. Maintain a reserve supply of hay.
   b. Plant Sudan grass for late summer feed.
   c. Use protein supplements during dry-grass season.

9. Furnish adequate technical assistance.

The determination of the quantity of needed "structural" measures in the range-improvement plan was made by consideration of the total needs and the anticipated accomplishment by going programs. The current accomplishments of the Agricultural Conservation Program of the Production and Marketing Administration and of the Soil Conservation Districts were projected over a 20-year installation period, then these quantities were subtracted from the total needed. The remainder includes the structural works needed for flood control, and is the quantities shown in table 2. Of the three groups of structural measures, it is anticipated that the Production and Marketing Administration program will have constructed, on private lands, all but 75 miles of fencing and 11 miles of gully stabilization. The remaining structural measures are on Federal lands.

Table 2.--Estimated cost of range-improvement program

Measure	Quantity	Installation cost	Operation, maintenance, and replacement
		Dollars	Dollars
Fencing	200 miles	1/113,100	5,600
Water development	50 units	28,300	1,400
Range reseeding	5,000 acres	113,500	5,700
Gully control	15 miles	93,000	1,000
Total		347,900	13,700

1/ Technical and educational assistance costs of approximately 7 percent are included in the installation costs on private land.

4. Farm-Land Measures

a. Community Channel Improvements.--An essential element to the proper functioning and effectiveness of the land-treatment measures in the farming area is the stabilization of farm and community waterways.

Installation of runoff-control measures on the land is often contingent upon improvement of community channels which serve as outlets for disposal of runoff. Soil-erosion control on the farm lands may require stabilization of outlet channels to prevent increased gully erosion and accompanying land damage. The improvement of these interdependent channels is included as an integral part of the farm-land treatment. These improvements consist of a wide variety of measures, application of which depends on specific site conditions.

The relation of community channels and their improvement to land treatment exists because of soils and physiographic conditions in the watershed. An appreciateion of the inter-relation depends on an understanding of these conditions and the effect of condition of flood water and sediment source areas on stream regimen in alluvial soils. The characteristics of agricultural soils are briefly described in Appendix 1, page 12. Proposed community channel improvements are largely located in old or recent alluvial soils. Stabilization measures are largely needed in stream reaches through recent alluvial soils. The degree of erosion or sedimentation activity in these minor streams is, among other things, a function of the amount of floodwater and sediment discharged into them from agricultural source areas. Present stream characteristics vary from those of extremely active gullying to poorly defined stream courses which change location with each deposition-producing runoff.

Intensification of land treatment and continuation of "going" land-treatment programs involve reduction in soil erosion and controlled disposal of runoff. Both of these items will increase erosional activity in alluvial streams' courses. Where small streams are now poorly defined, improvements have to be made to provide for orderly disposal of farm-land runoff. This definition of the runoff pattern must be carried to points of safe disposal and reduction in erosion on farm land must not be allowed to increase erosion activity and damage at other points along stream courses. For these reasons community channel improvements are essential for installation of related measures on farm land, to insure downstream sediment reduction benefits, and to prevent local flood damage along their courses.

Protection of agricultural land from bank cutting by revetments located along unstable reaches is recommended for Calleguas Creek and its upstream reaches--Arroyo Las Posas and Arroyo Simi. While complete and necessarily expensive flood control cannot be justified, bank protection to prevent loss of valuable agricultural lands is warranted in areas of apparent bank cutting activity. Measures for both needed bank protection and anticipated need for stream-bottom stabilization are recommended to insure effectiveness of the program in reducing the quantity of sand for deposition in stream reaches on the Oxnard plain.

Measures recommended for improvement of minor tributary streams in the Calleguas Creek watershed may include a few small floodwater-retarding structures where such structures will reduce the over-all cost of needed measures. The latter would consist of such stabilization measures as revetments, lined channels, drop structures, or earth section depending on requirements of field conditions.

Tributary channel improvements are needed in the vicinity of Somis to complete stream stabilization work undertaken by the Soil Conservation Demonstration Project in the period of 1933 to 1940. These improvements for stabilization of deeply incised barrancas and their tributary flows consist largely of drop structures and revetments.

Stabilization, enlargement, and bank protection of these tributary streams provide outlets for farm-land runoff systems as well as directly reducing flood and sediment damage. The Las Posas area requires drop structures to complete barranca stabilization started by the demonstration project. Disposal of runoff from areas tributary to the barrancas requires additional definition and stabilization. These measures are to reduce sediment contribution from stream erosion, provide stable outlet for farm-land measures, and reduce local flood damage. On the Oxnard plain channel excavation is needed to convey water from Las Posas Wash and local runoff in the vicinity of Del Norte Avenue and Santa Clara Avenue to the Santa Clara River. This program estimate also includes construction of earth channel sections for disposal of water in Pleasant Valley along the Camarillo Hill front.

Estimated needs for control of runoff in agricultural areas tributary to the Santa Clara River include completion of the runoff disposal systems started under public works programs in several areas and other improvements for direct control of local flood problems, disposal of runoff from farm lands, and land treatment for soil erosion control.

Measures for runoff control which are adapted to problems in the agricultural area along the north side of the valley between Ventura and Santa Paula include lined channels, conduits, drop structures, revetments, and earth channels for stabilization of adequate water disposal systems. East of Santa Paula prevention of flood damage by small tributary streams involves debris control as well as water disposal. Estimated costs include improvements for such recognized problems as Nigger Canyon at Piru and several small unnamed canyons west of and tributary to Sespe Creek. Measures include debris basins and required channel stabilization and enlargement for conveyance of flow to the main streams.

In the upper basin flood protection of agricultural land, along tributaries to the Santa Clara River, is largely one of bank protection of localized stream reaches.

The land-treatment program consists of soil-erosion control measures for reduction of floodwater and sediment damage. Most of the total of some 205,000 acres of farm land is estimated to need some of the practices not now being applied. The estimated quantities of farm-land measures needed are based on land use by land capability classes (table 3), conservation program specifications for each land-use and site class, and estimate of the adequacy of current (1948) conservation management in the watershed. Land-use capability (table 3) is developed from reconnaissance soil surveys of the watershed and land-use data taken from aerial photographs. Estimates of quantities of conservation measures needed in 1948 were expanded from available estimates for similar land-use and site conditions in soil conservation districts.

Description of the land in each capability class, shown in table 6, is as follows:

Class I — land is very good land with little or no limitation or hazard. It is nearly level, deep, and without erosion. Some of it may need drainage, clearing, or other conditioning measures.

Class II — land is good land with only minor limitations or hazards, such as gentle slopes, moderately shallow soils or slight susceptibility to erosion. Choice in use may be reduced, and conservation practices, such as water management, contour operation, cover cropping, etc., are required.

Class III — land is fairly good land which is suitable for occasional cultivation--usually not more frequently than 1 year in 4. When plowed, considerable care needs to be taken to avoid erosion or other lasting damage.

Class V — land is very well suited for grazing or forestry use. It has little or no physical limitations or hazards when so used but requires good range or woodland management.

Class VI — land is well suited for grazing or forestry use. It has minor hazards and limitations due to moderately steep slopes, shallow soils, or susceptibility to erosion.

The total program needed includes, where applicable, such practices as crop-residue management, contour tillage, annual winter cover crops, contour subsoiling, and strip cropping in addition to those measures shown in tables 4 and 5. These types of practices are now being applied in varying degrees under existing conservation programs.

Table 3.--Land use by land-use classes: Ventura County watersheds

Area and capability class	Citrus	Walnuts	Apricots	Truck and field crops	Alfalfa	Beans, beets, etc.	Grain and hay	Total by land use classes
	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Calleguas Creek								
I	2,425	7,085	400	1,725	500	11,075		23,210
II	3,180	7,340	500	1,655		14,600	1,200	28,475
III	1,480	410	2,900	300	200	4,880	2,920	13,090
IV	1,110		600			4,280	7,490	13,480
VI	1,585		250			4,130	6,975	12,940
Subtotal	9,780	14,835	4,650	3,680	700	38,965	18,585	91,195
Santa Clara and Ventura River watersheds								
I	13,400	8,560	230	4,160	4,020	15,470		45,840
II	15,680	890	450	3,010	4,920	13,250	2,900	41,100
III	2,945			450	520		8,205	12,120
IV	1,800						2,430	4,230
VI			500				500	1,000
Subtotal	33,825	9,450	1,180	7,620	9,460	28,720	14,035	104,290
Grand total	43,605	24,285	5,830	11,300	10,160	67,685	32,620	195,485

The 1949 records of practice payments by the Agricultural Conservation Program of the Production and Marketing Administration and Soil Conservation Service, showing application of conservation practices applied in the several soil conservation districts in the watershed, were used to project expected accomplishment by going programs of the Department over a 20-year installation period. These quantities were subtracted from total needs to obtain the intensified program (tables 4 and 5). Accomplishment by going programs indicated that, in the next 20 years, application could be expected for some simple and inexpensive practices mentioned above and for all conservation practices which do not involve costs above normal operation expenses. Tables 4 and 5 show the measures, their quantities, and costs remaining in the intensified agricultural land-treatment program.

Descriptions of these measures and total quantities for Calleguas Creek, Santa Clara, and Ventura River watersheds follow tables 7 and 8.

Table 4.--Intensified agricultural measures: Calleguas Creek watershed

Measure	Unit	Quantity	Installation cost 1/
			Dollars
Farm runoff disposal systems			
Land capability			
Class II	Acres	6,900	51,700
Classes III-VI	Acres	3,700	198,000
Irrigation system improvement	Acres	600	48,100
Terraces or diversion systems	Acres	1,740	46,500
Seeding to grass	Acres	17,400	372,400
Community channel improvement			3,002,000
Total			3,718,700

1/ Includes 7 percent for technical services and educational assistance.

Table 5.--Intensified agricultural measures: Santa Clara and Ventura River watersheds

Measure	Unit	Quantity	Installation cost 1/
			Dollars
Farm runoff disposal systems			
Land capability			
Class II	Acres	6,700	50,200
Classes III-VI	Acres	1,600	85,600
Irrigation system improvement	Acres	800	64,200
Terrace or diversion systems	Acres	4,300	114,000
Seeding to grass	Acres	2,900	62,000
Community channel improvement			3,006,700
Total			3,382,700

1/ Includes 7 percent for technical services and educational assistance.

b. Farm Runoff Disposal Systems.--Based on detailed study in Simi Valley Soil Conservation District and expanded to include all orchards in these watersheds, it has been estimated that 13,900 acres of land will require improvement of runoff disposal facilities. The improvements range from interception ditches with no outlet improvements or small infrequent structures to complete pipelines and inlet disposal systems on steep erodible land. These measures are to prevent soil erosion or sediment production and to provide for orderly conveyance of flow to improved community channels. This item does not include water disposal on grain-land which is covered in item d. below.

c. Irrigation System Improvement.--Irrigation systems on the older citrus orchards were installed years ago when erosion control was not recognized as a factor in planting furrow systems. Severe erosion by irrigation water moves much sediment into runoff disposal channels where it becomes part of the damaging sediment load transported by stream flow. Correction of these systems by such measures as additional distribution lines, change in furrow irrigation grades or use of sprinkler irrigation will be needed on about 1,400 acres of steep citrus land.

d. Terracing and Diversion Systems.--These measures are primarily applied to dry-farmed Class III land used for hay, grain, or bean production. They are part of needed controls on lands which are among the highest sediment-producing lands in the watershed. Approximately 6,100 acres of dry-farmed cropland are estimated to need these runoff control measures. Primary value is to erosion control or conservation of agricultural resources now being most rapidly destroyed on these sites and under this land use.

e. Grass Seeding.--Approximately 20,300 acres of land not suitable for continuous cultivation is now farmed to hay, grain, and beans. The land is a critical sediment source and in the 50-year history of cultivation, many acres have already eroded to the point that cultivation is no longer profitable. This eroded land then reverted to a poor quality of annual pasture under which erosion continues. It is planned that these areas be seeded to permanent pasture grasses while sufficient soil resources remain to support grass. This will minimize erosion and insure maximum productivity under proper land use.

Estimated total installation cost of the farm-land treatment measures is approximately $7,101,400. Distribution of installation cost by watersheds is shown in tables 6 and 7.

Table 7.--Cost of intensified farm-land measures: Santa Clara and Ventura River watersheds

Measures	Installation				Annual operation, maintenance and replacement		
	Federal	Other public	Private	Total	Other public	Private	Total
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
Farm runoff disposal systems							
Land capability Class II	25,100		25,100	50,200		1,900	1,900
Land capability Classes III-VI	42,800		42,800	85,600		3,200	3,200
Irrigation system improvement	19,300		44,900	64,200		2,400	2,400
Terrace or diversion systems	74,100		39,900	114,000		4,300	4,300
Seeding to grass	37,200		24,800	62,000		0	0
Community channel improvement	2,405,400	601,300		3,006,700	83,000		83,000
Total	2,603,900	601,300	177,500	3,382,700	83,000	11,800	94,800

The costs of land-treatment measures are based on sample conservation plans involving installation of these measures under a variety of site considions. Unit costs are those prevailing in 1948. These items, involving relatively high installation cost, are the phase of the complete program which requires intensification for completion in the installation period.

The cost and quantities of community measures primarily for flood control have been estimated by specific problem consideration where information warranted, and by expansion of this information to other similar areas when information was not available for specific consideration. These estimates were based on the following unit costs:

Item	Unit	Unit cost
Common excavation	Cubic yard	\$0.25 - 0.40
Earth embankment (including incidentals)	Cubic yard	\$0.75
Revetments, single pipe and wire	Linear foot	\$1.50
double pipe and wire	Linear foot	\$3.50
rail and wire	Linear foot	\$5.00
Reinforced concrete	Cubic yard	\$60 - \$100
Bank protection planting	Linear foot	\$0.30

SUMMARY OF PLAN OF IMPROVEMENTS COSTS

Total estimated installation, operation, and maintenance costs for the intensified watershed-treatment program are given in table 8.

Table 8.--Summary of costs of recommended program, by measures

Measure	Installation cost	Annual operation and maintenance
	Dollars	Dollars
Fire protection	4,476,200	499,200
Land acquisition	47,200	--
Range improvement	347,900	13,700
Farm-land improvement	7,101,400	181,200
Total	11,972,700	694,100

PHYSICAL EFFECT OF THE PROGRAM

The aim of the forest, range, and farm-land measures is two-fold.

1. To protect soils against high-intensity rains by improving plant cover or farm-land use, thereby increasing surface infiltration and reducing soil erosion.

2. To increase the effectiveness of land-use measures by supplemental structures on the land.

To show the effects of the land-use measures in comparable terms, they were expressed as "resultant" cover densities. Table 9 gives these cover densities by subdrainage areas. Column 2 shows present cover density which expresses the average protective condition of the land under present use. Column 4 is comparable in that it gives future total cover densities with the trends in present land use continuing and after the proposed land-use measures have become effective. This table shows that in all areas cover density will decrease over the present density, if present trends in land use continue. It shows marked improvement over present conditions, if the proposed program is put into effect.

The improvement in cover density reduces not only the large river discharges but also sedimentation. The result is a material reduction in flood peaks and flood damages. The effect on damage reductions of supplemental structures which are an integral part of the land-use measures is included with them.

The combined physical effect of all the measures results in a reduction of about 44 percent in flood damages.

Sediment reduction by the program will amount to about 3,800,000 cubic yards annually.

In addition to the flood damage reduction benefits, there are a series of incidental benefits.

Reduction in the number of damaging forest and grass fires and the shift toward smaller fires will reduce fire suppression costs and loss of property by fire.

Better grassland cover and improved range management will gradually increase the grazing capacity of the land. Average cattle weights will be increased by about 15 percent, and the calf crop will be increased about 10 percent.

Cropland measures will prevent a decline in soil fertility and will maintain yields at or above present levels. Thus the income of farmers will be maintained and the agriculture of the watershed stabilized.

Table 9.--Resultant cover densities with and without a watershed-treatment program

Subdrainage	Drainage area (1)	Present average cover density (2)	Future condition (3)	Future cover densities (4)
	Sq. mi.	Percent		Percent
Santa Clara River near Saugus	355	37.60	Without program	31.30
			With program	45.45
Matilija Creek	55	50.70	Without program	46.70
			With program	58.80
Calleguas Creek	115	40.68	Without program	38.72
			With program	52.07
Coyote Creek near Ventura	41	45.62	Without program	41.72
			With program	53.26
Piru Creek at Piru	432	38.70	Without program	34.20
			With program	49.16
Sespe Creek near Fillmore	254	42.97	Without program	38.62
			With program	53.56
Santa Paula Creek	40	43.33	Without program	39.53
			With program	51.93
Ventura River	187	45.36	Without program	41.66
			With program	54.77

UNITED STATES DEPARTMENT OF AGRICULTURE

APPENDIX 5

PROGRAM APPRAISAL

Santa Clara and Ventura Rivers and Calleguas Creek

To accompany report on survey, flood control, Santa Clara and Ventura Rivers and Calleguas Creek, California

APPENDIX 5

PROGRAM APPRAISAL

INTRODUCTION

In the report area the natural cover has been adversely affected by activities related to man's occupation and use. Fires, improper grazing use, the development of agriculture and oil fields, and the construction of roads have resulted in the removal or deterioration of natural cover over wide areas. The inevitable result has been reduced infiltration rates in watershed soils, acceleration of runoff and erosion, decreased groundwater recharge, and decreased livestock and crop yields.

The remedial program in general is aimed at restoring and maintaining the maximum infiltration rates compatible with occupation and use of the watersheds, within limits of economic justification. The program also seeks to reduce the accelerated erosion which results in decreased channel capacities, impairs the value of water storage developments, and generally augments the damage caused by flood impact and inundation.

Previous appendices have described the various measures designed to reduce runoff and erosion from wild-, range-, and cropland. Their effect on peak discharges is shown in table 5, Appendix 2. In addition to direct benefits the recommended program will return benefits which are definite but difficult of evaluation.

Benefits and costs were estimated on the assumption of complete installation of treatment and farmer participation. A high degree of cooperation in the range and cultivated land treatment is expected in view of the present attitude and participation of farmers and ranchers in existing public programs. All monetary values given are in terms of prices that prevailed in the first half of 1948.

ANALYSIS OF BENEFITS

1. Flood Reduction Benefits.--Reduction of flood damages by the proposed program is $476,400 annually. The effect of the program measures on improvement of cover conditions is shown in table 9, Appendix 4, and in turn the effect of this cover improvement on flood peaks is shown in table 5, Appendix 2. The resultant flood damage reductions are derived from the frequency data in table 5 of Appendix 2, and the various discharge damage curves based on data in tables 3 to 13 of Appendix 3, and are listed in table 1 of this appendix.

The flood damage reductions shown in table 1 include the effect of "going" programs of Department of Agriculture agencies during the next 20 years--the installation period of the recommended flood-control program. The average annual benefit from the accelerated cover-improvement program proposed herein is estimated at $431,300 which, together with structural measures, gives a total benefit of $476,400 annually, or $543,100 if future increases in population and economic development are considered.

Table 1.--Average annual flood damage with and without cover improvement measures

Area	Average annual damage: Future without program	Average annual damage: Future with program	Total average annual damage reduction
	Dollars	Dollars	Dollars
Santa Clara River and tributaries above Piru Creek	514,300	232,200	282,100
Santa Clara River between Piru Creek and South Mountain	299,000	173,500	125,500
Piru Creek	20,200	14,700	5,500
Sespe Creek	22,900	11,300	11,600
Santa Clara River barrancas and small tributaries	55,100	39,500	15,600
Ventura River to levee	94,800	63,000	31,800
Horn and San Antonio Creek	14,700	9,100	5,600
Calleguas Creek below Moorpark	19,900	12,300	7,600
Tributaries to Calleguas Creek above Conejo Creek	19,600	14,100	5,500
Conejo Creek	6,300	3,600	2,700
Las Posas Creek	21,100	18,700	2,400
Total	1,087,900	592,000	1/495,900

1/ Of this amount, $431,300 is attributable to measures recommended in this report; the remainder will result from going programs of the Department of Agriculture in the next 20 years. This total does not include the effect of future increases in population and development which was estimated on page 13, Appendix 3. If future conditions are considered this total would be $565,300, of which $491,700 would be attributable to measures recommended in this report.

Revised May 1952

2. <u>Sediment Reduction Benefits</u>.--Two broad classes of sediment reduction benefits have been evaluated, namely, the reduction of sedimentation in (a) reservoirs, and (b) channels. Although three reservoirs are in operation in this basin, the effect of reduced sedimentation has been calculated only for the recently constructed Matilija water conservation reservoir. This reservoir was completed in 1949 at an estimated cost of $2,373,340. The original capacity of 7,000 acre-feet has a life of 72 years at the present and expected future rate of sedimentation without a watershed treatment program. With the recommended program the life of this reservoir could be extended to 200 years. The value of reducing sedimentation in this reservoir was determined by the cost of replacement plus loss in service with and without a program. Loss in service was assumed to be the value of each acre-foot of water which would be displaced each year by the average annual rate of sedimentation. The value of an acre-foot of water was assumed to be equal to the present average price paid for water in this area which is $20 per acre-foot.

The benefit resulting from reduced sedimentation was determined as follows:

1.	Useful life of reservoir without program, years	72
2.	Useful life of reservoir with program, years	200
3.	Replacement cost of capacity lost	$2,373,340
4.	Average annual damage without program ($2,373,340 x sinking fund factor .0025)	$5,933
5.	Average annual damage with program ($2,373,340 x sinking fund factor .000016)	$38
6.	Annual increment of service loss without program (Average annual sedimentation rate (97 acre-feet) x $20)	$1,940
7.	Annual increment of service loss with program (Average annual sedimentation rate (35 acre-feet) x $20)	$700
8.	Present worth of service loss without program ($1,940 x 504.5326, present worth of an annuity increasing by 1 per year for 72 years at 4 percent interest)	$978,793
9.	Present worth of service loss with program ($700 x 619.9023, present worth of an annuity increasing by 1 per year for 200 years at 4 percent interest)	$433,932
10.	Average annual equivalent value of service loss without program ($978,793 x .04252, amortization factor for 72 years)	$41,618
11.	Average annual equivalent value of service loss with program ($433,932 x .04000, amortization factor for 200 years)	$17,357
12.	Average annual damage without program (4. plus 10.)	$47,551
13.	Average annual damage with program (5. plus 11.)	$17,395
14.	Average annual benefit (12 - 13.)	$30,156

Stream channel sedimentation in this watershed is less susceptible to adequate evaluation at the present time. Although estimates of erosion have been made for the several sub-basins, sufficient data are not available to determine the full effect of sedimentation on the main channels of the Ventura and Santa Clara Rivers. Available river channel measurements are limited to a relatively short span of time and do not include periods immediately before major flood discharges. Consequently, no attempt has been made to evaluate the effect of sediment reductions in the main channels of the Ventura and Santa Clara Rivers. Nonetheless significant reductions in sediment deposited in these channels will be made as a result of the recommended program.

Unlike the Santa Clara-Ventura Rivers, deposition and its effect on channel capacity has been established in Calleguas Creek. Excavation of this channel is a recurrent operation by local interests, therefore it has been assumed that maintenance of this channel will be continued in the same manner in the future. The estimated average annual sedimentation rate without the recommended program is 323,000 cubic yards. The recommended program will reduce this rate about 68 percent or 218,000 cubic yards annually. Of the total sedimentation rate it is assumed that slightly more than half remains in the channel, the balance being carried to the ocean by stream discharges. On the basis of current operations it is estimated that about 33 percent of the sediment will be deposited in the area between the dikes and U. S. Highway 101 where the average annual cost of removal will be $1.30 per cubic yard. About 19 percent will be deposited below the highway where the average annual removal cost will be $0.50 per cubic yard. The benefit for reduced sedimentation in Calleguas Creek channel is calculated as follows:

Sedimentation rate without program	323,000 cubic yards
Sedimentation rate with program	104,200
Reduction due to program	218,800
Estimated annual cost of channel maintenance without program	$133,000
Estimated annual cost of channel maintenance with program	$ 43,000
Average annual benefit	$ 90,000

Approximately 90 percent of benefit will result from recommended program, 10 percent from "going" program, therefore average annual benefit is $81,000.

The recommended program is expected to accomplish about 80 percent of this reduction immediately upon installation of the watershed treatment measures. The remaining 20 percent may require up to 10 years to accomplish. Of the $81,000 annual benefit, 20 percent was discounted for 10 years which reduced the average annual benefit from reduced sedimentation in Calleguas Creek channel to $77,500.

3. Conservation and Other Incidental Benefits.--Aside from the benefits described so far the measures proposed in Appendix 4 yield benefits incidental to their installation. The total of these incidental benefits is $571,000 and the contribution of each of the measures is discussed below.

(a) Fire-Control Measures.--Three types of incidental benefits accrue from these measures--reduction in fire suppression costs, reduction of property loss by fire, and decreased maintenance cost of roads.

The saving in fire suppression cost is attributable to the decrease in average annual acreage of burn. Better detection of fires and more rapid attack will reduce the number of acres burned by individual fires. The reduction in average annual rate of burn will require an increase in prevention costs but will effect a reduction in suppression costs. The savings are calculated to be $81,900.

Along with the reduction in size of fires will be a reduction in property damage by fires. Less range forage, fences, buildings, and stored feed will be destroyed. From records of the U. S. Forest Service it is estimated that the average property loss from fire in the national forest portion of the report area would be $1.68 per acre. For the portion outside the national forests, records were available for the section protected by Ventura County.

In the past the years the property losses have ranged from $1,300 to $186,000 per year in zones 1 and 2 which include the foothill land adjacent to the national forests. In zone 3, which includes the areas outside cities and towns and the lower foothill farming lands, the average annual property losses have ranged from 0 to $90 per acre burned, with a 10-year average of $4.65 per acre. These losses are as reported by Ventura County and are not increased to reflect present or future price levels. The fire losses in zone 3 were not considered, and the one abnormally large annual loss of $186,000 in zones 1 and 2 was omitted in determining an average annual property loss of $1.93 per acre for the wild land fires outside the national forest zone of responsibility.

Thus the expected average annual reduction of 20,100 acres burned in the Forest Service protection zone, and the 12,600 acres in the Los Angeles and Ventura County protection zones will result in an average annual reduction in direct fire damages of $57,700.

Road maintenance costs in areas burned by fire are above normal for several years following a fire. With a reduction in the area burned there would be a reduction in road maintenance costs. The calculation of reduction in road maintenance cost expected to result from increased fire control was based on studies made for a flood control survey on the adjacent San Gabriel River watershed. In that area road maintenance records showed that fires caused increased maintenance costs for affected roads for about four years following fires. Based upon those records and the frequency and size of storms expected in the four-year period, it was calculated that the increased maintenance costs would be $3,758 per mile for minor roads and $22,170 for major roads, per year. These increased maintenance costs, after revision to 1948 price levels ($7,140 and $42,123 respectively) were adopted for use in the Ventura-Santa Clara River area. It was assumed that the reduction in mileage of road affected each year by fire was proportional to the percentage reduction of burn of brush cover which was expected to result from increased fire control.

Data on the Forest Service road system show there are a total of 769 miles of roads in the national forests, exclusive of major highways. For purposes of this study the only roads considered as major highways in the wild-land area were the Ventura-Maricopa road (U. S. Highway 399) and the Los Angeles-Bakersfield road (U. S. 99). Other roads which might be classed as major roads from the standpoint of importance and volume of traffic are included in the Forest Service network, so the entire mileage of this network was considered herein as minor. For this purpose only roads within the national forests were used as it was considered that, in general, this was the area of rugged relief such that denudation by fire would cause increased debris movement and additional maintenance work. A few miles of private and county roads within the national forests but not part of the Forest Service network were also included as minor roads. No mileage within the Calleguas Creek watershed was included.

Of the total mileage of roads in the national forest area used in the study, it was estimated that 40 percent to 50 percent, depending on general location, would be likely to suffer increased maintenance costs due to fires. Fire control studies have shown that the probable average annual rate of burn in the report area in the future without an intensified control plan would be 3 percent of the protection zones. The program recommended is expected to hold the average annual burned area to 0.2 percent. This percentage reduction in area of fires was applied to the road mileages discussed above with the result that expected increased maintenance costs would be eliminated on 9.7 miles of minor roads and 0.53 miles of major roads annually, with a corresponding saving of $92,000. There would also be a similar reduction in expected fire-caused increase in maintenance and upkeep of other utility lines such as railroads, telephone and telegraph lines, power transmission lines, aqueducts, water, gas, and oil pipe lines, etc., but data are not available to permit monetary evaluation.

(b) Range-Land Measures.--It is estimated that 25,000 head of cattle are grazed in the Ventura-Santa Clara-Calleguas drainages. Expressed in animal units this represents 17,800 animal units. The program proposes better use of the range by increasing water development, fencing, and seeding to more desirable grasses. Increase in protein supplements during the months of low nutritive value of the range is also required. It is estimated that such measures will increase cattle weights by 15 percent and the calf crop by 10 percent. The total number of cattle expressed in animal units will increase to about 18,500.

Ordinary ranch operating costs (excluding rent, interest on capital invested in land, and real estate taxes) will increase from $20.40 per animal unit to $29.20 per animal unit as a result of an addition of 150 pounds of cottonseed meal (or similar concentrate) to the diet, greater demand for labor, horse, and truck work, etc. However, gross returns will also rise from $62 per animal unit under present management to $77 per animal unit with the proposed management practices. Major emphasis is placed on rotation of the grazing area, developing

under-grazed areas and improving over-grazed areas. Supplemental feeding would be used in conjunction with rotated use to accomplish the objectives. Although on-site benefits would accrue almost immediately because of weight and calf crop increases, it has been assumed that a maximum period of 10 years after installation would be required for full accomplishment of both on-site and off-site benefits.

Ranch operating costs were calculated as indicated in table 2.

Revised May 1952

Table 2.--Estimated ranch operation costs

Item	Unit costs: With program	Unit costs: Without program
	Dollars	Dollars
Hay	.96	.96
Concentrate	7.23	.48
Other feed	.08	.08
Salt	.12	.12
Labor	7.71	6.18
Horse work	.58	.46
Vaccine	.18	.18
Auto and truck	1.38	1.11
Depreciation	2.62	2.48
Association fees	.05	.05
Taxes	.97	.97
Interest	7.14	7.14
Miscellaneous	.16	.16
Total	29.20	20.40

Table 3 gives the sample calculations for determining the gross returns per animal unit based on samples of 1,100 and 1,150 animal units.

Table 3.--Gross ranch returns, with and without the recommended program

	With program 1/				Without program 2/			
	Calves	Yearlings	2-year olds	Cows	Calves	Yearlings	2-year olds	Cows
Return per 100 lbs.	$23	$25	$25	$15	$23	$25	$25	$15
Number sold	183	98	152	89	158	85	132	89
Average weight, lbs.	393	846	987	1,042	342	736	858	906
Return per head	$90	$210	$247	$153	$79	$184	$215	$136
Total return	$16,380	$20,580	$37,400	$13,620	$12,480	$15,640	$28,380	$12,100

1/ Based on calculated sample of 1,150 animal units.

2/ Based on actual sample of 1,100 animal units.

The on-site or conservation benefits of the range measures were calculated as follows:

Present net return per year without program	$ 740,900
Net return per year 10 years hence with program	881,900
Gain in return	141,000
Average annual rate of increase	14,100
Present value of increase	592,091
Increase in income 10th year	141,000
Increase in income capitalized at 4 percent	3,525,000
Present value of increased income 10th year	2,381,134
Present value of increase in income	2,973,225
Average annual equivalent value	118,929
"Going program" will accomplish 50 percent of increase, therefore benefit resulting from recommended program is	59,434

(c) Farm-land Measures.--The farm-land measures proposed in Appendix 4 yield major soil conservation benefits. The measures are expected to maintain agricultural yields at or above present levels under conditions of proper land use. Quantitative evaluation of conservation benefits has been based on observation and judgment by local authorities on agricultural production and conservation. No applicable studies or investigations have been made to evaluate conservation benefits for these land-use conditions.

Monetary appraisal of conservation benefits is made only for major land uses of citrus, beans, and grain production on sloping land. The approach used has varied with crops and soil conditions to utilize most tangible judgment of the effect of prevention of soil loss on agricultural production. The evaluation has been made by land-use capability classes and for site conditions of limited soil depth. Specific estimates are shown in tables 4 and 5, and are briefly discussed as follows:

It is generally recognized that citrus groves have a limited economic life, even under the best of site and management conditions, of perhaps 75 years. Evidence indicates that under less favorable soil conditions, with limited root zone, and with erosional loss of soil, the economic life will be decreased. Both amount of production and net income will be correspondingly lowered.

Estimate of benefit to all Class II and III land used for hay or grain is based on maintenance of production at present level in comparison to projected deterioration to the point where grain farming is not profitable on soils of limited profile and to a lower level of production on soils of relatively unlimited profile. When topsoil resources are lost by erosion on limited profiles, land use is assumed to revert to poor range.

A similar approach is used in estimating benefits of a conservation program to prevent erosion on dry-farmed bean land.

Table 4 shows present production quantities and values used for the site conditions involving limited soil depth on Class III, IV, and VI land.

Table 4.--Estimated value of conservation practices, farm-land measures, Ventura County watersheds

Land use	Class	Present: Net return per box	Present: Boxes per acre	Future production: No conservation program: Years until no net return	Future production: Recommended program: Years until no net return	Estimated annual equivalent value of conservation program per acre
		Dollars				Dollars
Citrus						
Limited soil depth	II	1.00	250	50	75	29.71
Limited soil depth	III & IV	.65	200	40	60	15.89
Limited soil depth	VI & VII	.37	150	30	45	6.74

Land use	Class	Present return: Biannual yield	Present return: Annual net per acre	Future return: Without proposed program: Years until decline to range or yield	Future return: Without proposed program: Annual net return as range	Future return: With proposed program: Biannual yield	Future return: With proposed program: Annual net per acre	Estimated annual equivalent value of conservation program per acre
			Dollars		Dollars			
Grain								
Limited soil depth	II	25 bu.	9.00	50 yrs.	.25	25 bu.	9.00	3.91
Limited soil depth	III	20 bu.	3.50	30 yrs.	.25	20 bu.	3.50	1.95
Limited soil depth	IV & VI	12 bu.	none	20 yrs. (within install. period)	.20	range 1/3 aum/acre	1.00	.80
Unlimited soil depth	II & III	30 bu.	7.30	27 yrs.	5.50	30 bu.	7.30	1.13
		Sacks per acre				Sacks per acre		
Beans								
dry farmed	III	8	60.00	50 yrs.	8.00	8	60.00	22.68
dry farmed	IV & VI	3	13.00	30 yrs.	8.00	range 4 aum/acre	16.00	4.79

Table 5.--Cropland conservation benefits

Watershed	Land use and soil depth	Land capability class	Quantity	Unit value	Total	
			Acres	Dollars	Dollars	
Santa Clara	Citrus (Shallow Soil)	II	2,780	29.71	82,594	
		III	2,920	15.89	46,399	
	Grain (Shallow Soil)	II	250	3.91	977	
		III	1,115	1.95	2,174	
		IV	1,430	.80	1,150	
Subtotal						133,294
Ventura	Grain (Shallow Soil)	II	1,000	3.91	3,910	
		III	2,280	1.95	4,446	
		IV, VI	1,500	.80	1,200	
	(Deep Soil)	II, III	1,520	1.13	1,702	
Subtotal						11,258
Calleguas Creek	Citrus (Shallow Soil)	II	175	29.71	5,199	
		III, IV	2,520	15.89	40,043	
		VI, VII	1,585	6.74	10,683	
	Grain (Shallow Soil)	II	640	3.91	2,502	
		III	2,920	1.95	5,694	
		IV, VI	14,465	.80	11,570	
	(Deep Soil)	II, III	560	1.13	633	
	Beans, (Shallow Soil)	III	3,920	22.68	88,906	
	Beans, (Shallow Soil)	IV, VI	8,390	4.79	40,188	
Subtotal						205,418
Grand total						$349,970

Deterioration of lands under these conditions is very apparent in the country. Conservation benefit has been estimated as the difference between net income under proper land use and management and net income under projected rate of deterioration and ultimate use as poor range when cultivation ceases to be profitable.

Total conservation benefits are given in table 5. The "going program" of the Department is expected to accomplish 20 percent of the total benefits calculated, therefore the conservation benefits resulting from the measures recommended in Appendix 4 are estimated to be $280,000.

4. Nonevaluated Benefits.--In addition to the evaluated benefits of the recommended program, it will return many other indirect and intangible benefits which are difficult of accurate evaluation. These have been described in the main report section, and were developed from the data and material of the preceding appendices.

ANALYSIS OF COSTS

1. Installation Cost.--The total installation cost of the proposed measures is $12,715,900, as is shown in table 6. The share that each group of measures contributes to this sum is described below.

(a) Fire-Protection.--The total cost of these measures is $4,476,200. Table 1 of Appendix 4 gives these costs by the various protection agencies. The cost on land protected by Los Angeles County will be $473,700; on land protected by Ventura County it will be $1,266,400. The cost on the national forests will be $2,736,100. It is proposed that 50 percent of the cost to Los Angeles and Ventura Counties be assumed by the Federal Government in addition to the cost of installing the measures on the national forests.

The total cost to the Federal Government will be $3,606,200, as is shown in table 6.

Purchase of 2,810 acres of scattered tracts of privately owned land within Los Padres National Forest will cost approximately $47,200, to be paid by the Federal Government.

(b) Range Improvement Measures.--Fencing, water development, and range reseeding are the major items of installation needed besides greatly improved management. The installation measures needed are shown in table 2 of Appendix 4. The total cost is $347,900. All except 75 miles of fences and 11 miles of gully stabilization are on Federal land. The cost on private land is $117,400 and it is proposed that the Federal Government contribute to this expenditure at the same rate as the present participation under the Agricultural Conservation Program, or about $54,500. The total cost to the Federal Government therefore would be $285,000.

(c) Farm-Land Measures.--The cost of the various farm-land measures is shown in detail in tables 6-7, Appendix 4. The cost is about $7,101,400, being about equally distributed between the Calleguas Creek drainage and the Santa Clara-Ventura River drainages.

The cost of community channels is $6,008,700. The distribution is such that local interests pay for all rights-of-way and a portion of the

installation cost, both of which amount to $1,201,700. The Federal Government should pay for the remainder, or $4,807,000.

The distribution of the cost between the Federal Government and individuals for all other measures on farm land follows the rates of current Federal participation on such work under the Agricultural Conservation Program. This means a Federal expenditure of $591,400 and an expenditure by farmers of $501,300.

A summary of the distribution of costs by sources of funds is shown in table 6.

Table 6.--Distribution of installation costs by source of funds

Measure	Federal	Other public	Private	Total
	Dollars	Dollars	Dollars	Dollars
Fire protection	3,606,200	870,000	0	4,476,200
Land acquisition	47,200	0	0	47,200
Range improvement	285,000	0	62,900	347,900
Farm-land improvement	5,398,400	1,201,700	501,300	7,101,400
Total	9,336,800	2,071,700	564,200	11,972,700

2. Operation, Maintenance, and Replacement Cost.--The annual cost of operation, maintenance, and replacement of the total proposed program is $694,100.

The maintenance and operation of fire-protection measures is $499,200. It is proposed that the Federal Government pay the annual costs on Federal land and 50 percent of the annual cost for protection to the non-Federal lands. This would require $382,000 a year of Federal funds and $117,200 of State-county funds.

The cost for range-land measures is $13,700. Of all installation only 75 miles of fencing and 11 miles of gully control are on private land. Maintenance of these measures is $2,500 to be charged to ranchers; all the rest is to be paid out of Federal funds. Expenses to ranchers will further increase because of changes in their operations. This was shown previously (Conservation and Other Incidental Benefits, (b) Range Land). Their annual costs will increase by $175,400. This, however, is offset by higher returns and only the net effect is considered as a conservation benefit.

The total operation, maintenance, and replacement costs of farm-land measures is $181,200. All costs except community channels should be paid by farmers. The distribution is as shown in table 7--farmers $24,700, local agencies $156,500.

Table 7.--Distribution of operation, maintenance, and replacement costs by source of funds

Measure	Federal	Other Public	Private	Total
	Dollars	Dollars	Dollars	Dollars
Fire protection	382,000	117,200	0	499,200
Range improvement	11,200	0	2,500	13,700
Farm-land improvement	0	156,500	24,700	181,200
Total	393,200	273,700	27,200	694,100

COMPARISON OF COSTS AND BENEFITS

Average annual benefits of the program are estimated at $1,221,800, as summarized below:

Reduction in flood damage	$ 543,100 *
Reduction in channel sedimentation	77,500
Reduction in reservoir damage	30,200
Reduction in fire suppression cost	81,900
Reduction in property loss by fire	57,700
Increased range returns	59,400
Reduction in road maintenance cost	92,000
Maintenance of crop yields	280,000
Total	1,221,800

*Includes the effect of flood damages on increased future developments, discounted to the present. See page 13, Appendix 3.

The average annual cost of the groups of remedial measures is shown below, and consists of the annual operation and maintenance costs plus interest charges at the rate of 2 1/2 percent on Federal and public expenditures and 4 percent for private investments.

Fire protection and land acquisition	$612,300
Range-land treatment	23,300
Farm-land treatment	366,200
Total	$1,001,800

In the development of the program, structural debris stabilization was considered for several areas, including Matilija, Coyote Creek, Stewart Canyon, Sespe Creek, Santa Paula Creek, the upper headwaters of the main Santa Clara River, and Castaic Creek. None of these measures was found economically feasible at this time. It is possible that the construction of proposed water-conservation structures or changed economic conditions may warrant future investigation of plans for these areas.

RATIO OF BENEFITS TO COSTS

Throughout this report 1948 prices were used. To convert to price levels expected to prevail over long-term periods, indices were applied to the 1948 values. The 1948 prices were multiplied by the following ratios:

Prices received by farmers	.78
Prices paid by farmers	.83
Construction costs	.92

This reduces overall average benefits to $1,065,100 and overall annual costs to $938,300 with a resulting benefit-cost ratio of 1.1 to 1.0.